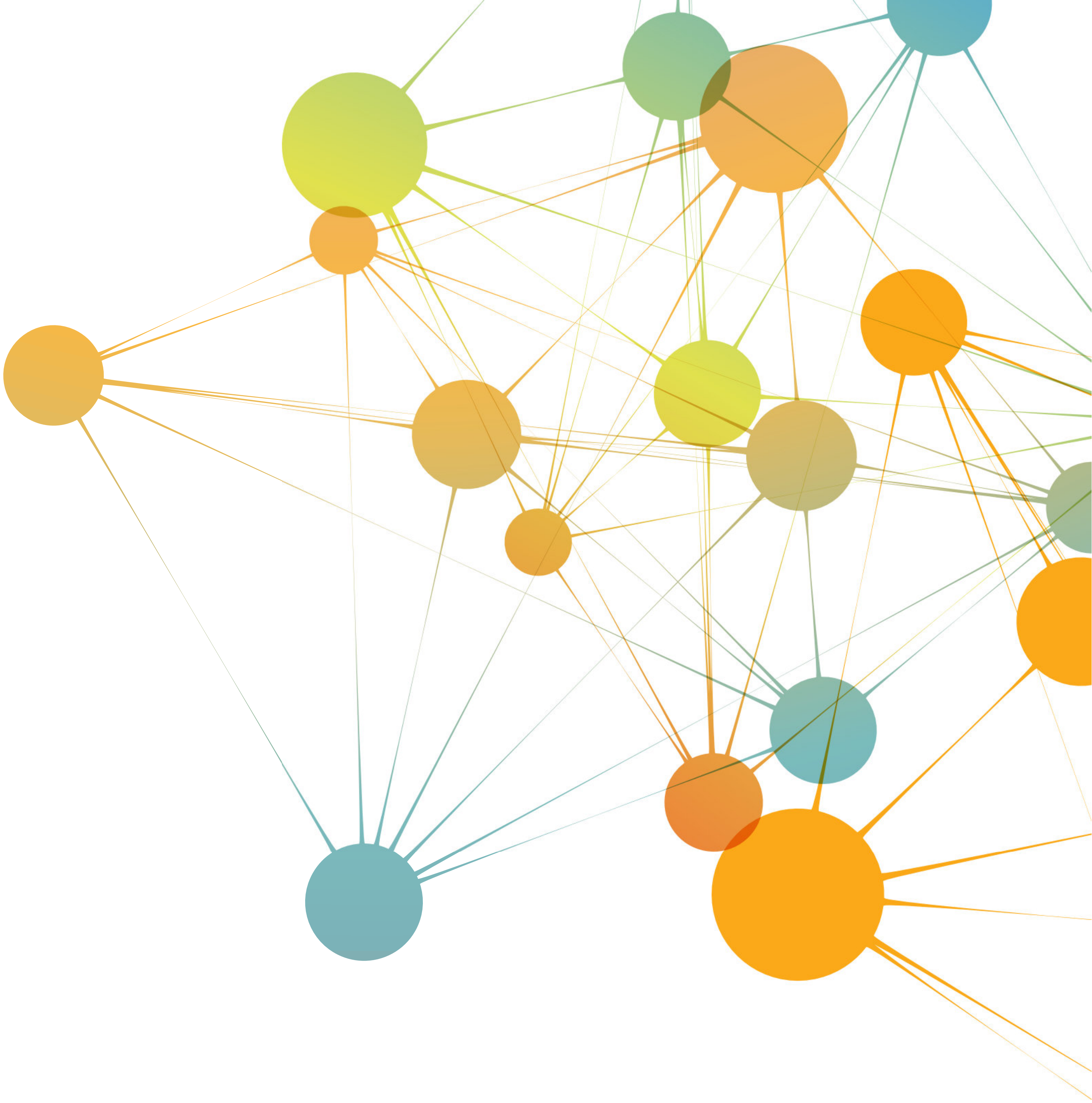

CREATEWORLD 2017

CREATIVITY ON THE MOVE

Conference Proceedings

AUC

Conference Committee
Tony Gray, Seth Ellis, Daniel Della-Bosca, Dale Patterson

"The CreateWorld 2017 papers contain cutting-edge and insightful research articles in the field of creativity applied through the use of technology. Overall we had 32 submissions, from which 17 were selected as full papers, and 3 as a poster presentations. Createworld 2017 also hosted 1 major performance by Dr Leah Barclay, 6 Community Sessions, 4 Community Workshops and 5 workshops hosted by our friends from Adobe Australia

All submissions were thoroughly evaluated in a review and meta-review process by the Program Committee consisting of distinguished experts from around Australia. We are grateful to all our reviewers and sub-reviewers for their hard, timely, and meticulous work that provided extensive and constructive feedback to all our submissions and had a decisive contribution to the success and high quality of this event.

The Keynotes for CreateWorld 2016 were **Dr Troy Innocent** from Swinburne University and **Dr Gary Grant** from Griffith University.

The paper refereeing process was conducted according to the specifications of the Australian Government for the collection of Higher Education Research Data
International Peer Reviewer Jury:
Dr Tim Kitchen, Adobe (Senior Education Specialist) & Swinburne University of Technology
Dr Jason Nelson, Griffith University (Fulbright scholar - Norway)
Dr Dale Patterson, Griffith University (Interactive Media, Visualisation & Immersive Design)
Mr Daniel Della-Bosca, Griffith University (Visualisation & Immersive Design)
Mr Seth Ellis, Griffith University (Interactive Media)

Published by: AUC and Griffith Centre for Creative Arts Research
C/- AUC PO Box 484 Carlton South
Victoria 3054AUSTRALIA
ISBN: 9781925455625

These proceedings are available online at

…….http://auc.edu.au/createworld/presentations-2017/

Accepted Papers

Combining Cooperative Design Patterns to Improve Player Experience
Lachlan Bunker & Reza Ryan

A Generic Architecture for an Ecosystem of Autonomous Artificial Animals using Dynamic Considerations
Christopher Osmond & Reza Ryan

Repurposing Augmented Reality Browsers for Acts of Creative Subversion on the Move
David Sargent

Complete Cinematic-style Immersion: Improving Interactive Music Soundtrack Design for the Dungeons and Dragons Table-top Roleplaying Game
Michael Drew & Ross McLennan

Millennials, Politics & Visual Communication
Rae Cooper

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The Real Thing: An Aesthetic Comparison of Modelled VersusTraditional Guitar Amplification Technology in the Studio
Rob Keko & Ross McLennan

Conceptualising Game Design – A Tangible approach to Level Design
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Performance Capture: Split between the Fictitious and Physical World
Joel Bennet & Chris Carter

Early Development of a Flexible Procedural Approach to Automatic Jazz Improvisation
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An Autonomous Music Composer based on Affective Principles
Jacob Olander

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Andy Aubun & Ross McLennan

Generating a Virtual Forest Environment Using Procedural Content Generation
Liam Potter & Reza Ryan

Exploring the Craft of Immersion in Virtual Reality
Shanice Hayes & Justin Carter

Approaches to Modular Construction for Real-Time Game Environments
Braiden Fenech & Justin Carter

Capturing Willandra – Challenges & Experiences Bringing a Hidden Historical Site to Interactive Digital Life
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Unreal Realities: Non-Photorealistic Rendering in Virtual Reality
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Accepted Poster Presentations

Island Healing: A Global Exploration of Sound Healing Ideas and Practices and the Implementation of These into Music intended To Make Peace with Place
Clara Durbridge & Ross McLennan

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Stevie Mills & Justin Carter

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Welcome

Welcome to **CreateWorld** - now in its 11th year, and the product of a wonderful and ongoing partnership between the AUC and the Queensland College of Art at Griffith University.

This year, our theme is “Creativity on the Move”. The ascendancy of mobile computing is a defining characteristic of computer technology over the last decade. The increasing power and decreasing size of mobile computing platforms has created new opportunities for teachers, artists, performers, developers, gamers and people in almost every other walk of life, allowing them to discover, create, explore, and share experiences in new ways. For CreateWorld 2017 we want to take a closer look at how mobile devices empower us, to explore the ways in which we interact with them, and consider what’s over the horizon..

The major conference tracks include peer-reviewed papers, presentations, workshops, an exhibition, and a performance that reflects upon Bill Duckworth and Nora Farrell’s engaging presentation on iOrpheus, the iPod orchestra project, at CreateWorld 2007.

No AUC event would be a success without the hard work put in by the paper authors, session and workshop presenters, exhibition contributors, and partners, and we thank them all for the many hours they’ve spent preparing, as well as the time they’ve given up to be part of the conference.

I’d particularly like to thank my co-chairs, Daniel Della-Bosca, Seth Eillis and Dale Patterson for the substantial work that they’ve done to bring everything together, and Rae Cooper for her extensive work in promoting CreateWorld on social media.

I hope that you find that the next 3 days inspire you, and that they are a rewarding and valuable use of your time that provides you with new perspectives on creativity.

I wish you a great conference!

Tony Gray,
Chair, AUC

Our Code of Conduct

We aim to provide welcoming and professional environments so that people regardless of age, race, gender identity or expression, background, disability, appearance, sexuality, walk of life, or religion can work together to share experience in the use of Apple technology.

Please be respectful of others and be courteous to those around you. We do not tolerate harassment or offensive behaviour.

Complaints about harassment or offensive behaviour may be made to the conference organisers. All complaints will remain confidential and be taken seriously.

Any person asked by an organiser, convenor or moderator to cease harassing or offensive behaviour must comply immediately.

At the discretion of the organisers, a person violating our code of conduct may be excluded from the conference without refund.

Unacceptable behaviour includes, but is not limited to:

- offensive verbal or written remarks related to gender, sexual orientation, disability, physical appearance, body size, race or religion
- sexual or violent images in public spaces (including presentation slides)
- deliberate intimidation
- stalking or following
- unwanted photography or recording
- sustained disruption of talks or other events
- disruptive intoxicated behaviour
- inappropriate physical contact
- unwelcome sexual attention
- sexist, racist, or other exclusionary jokes

Our full code of conduct can be found at:

http://auc.edu.au/policies/code-of-conduct/

Program

WED 29 NOVEMBER

10:00	10:00 Registration, Tea & Coffee Available 10:45 Welcome and Conference Opening - S05 QCA Lecture Theatre, Room 2.04
11:00	11:00 Keynote - Dr. Gary Grant S05 QCA Lecture Theatre, Room 2.04
12:00	12:00 Lunch S02 Webb Centre, Room 4.05B
1:00	1:00 Papers Track S02 Webb Centre, Room 4.02E
1:00–2:00	1:00 Augmented Reality in Education ... Stephen Atherton 1:45 Using VM Apps to Build Basic ... Garry Falloon 2:30 Mobile Listening: Augmenting Environ… Leah Barclay S02 Webb Centre, Room 4.02F
3:00	3:00 Afternoon Tea - S02 4.05B (Webb Centre) 3:30 Exhibition S02 Webb Centre, Room 4.02A
4:00	4:30 iOrpheus Panel, followed by iOrpheus Reflections Performance S02 Webb Centre, Room 4.02E, then outdoors Leah Barclay
5:00	

Program

THU 30 NOVEMBER

9:00	9:00 Papers Track S02 Webb Centre, Room 4.02E	9:00 Workshop: Unity and ARKit S02 Webb Centre, Room 3.07 Mac Lab	
10:00			
11:00	11:00 Keynote - Dr. Troy Innocent S08 Griffith Film School, Room 2.14		
12:00	12:00 Lunch S02 Webb Centre, Room 4.05B		
1:00	1:00 Papers Track S02 Webb Centre, 4.02E	1:00 Workshop: Teaching Coding on the iPad S02 Webb Centre, 4.02F	1:00 Workshop: Adobe Draw + Capture S02 Webb Centre, 4.02C
2:00			2:00 Workshop: Adobe Premiere Clip S02 Webb Centre, 4.02C
3:00	3:00 Afternoon Tea - S02 Webb Centre, Room 4.05B		
4:00			3:30 Workshop: Adobe XD S02 Webb Centre, Room 3.07 Mac Lab
5:00			
6:00	6:30 Conference Dinner Ship Inn		
7:00			
8:00			
9:00			

Program

FRI 1 DECEMBER

9:00	9:00 Workshop: Touch Designer Jason Haggerty S02 Webb Centre, Room 4.02C
	9:30 State of the AR Iain Anderson
10:00	10:15 Mix Your World with Holograms Thomas Verbeek S02 Webb Centre, Room 4.02F
11:00	11:00 Keynote - Dr. Tim Kitchen S02 Webb Centre, Room 4.02F
12:00	12:00 Lunch S02 Webb Centre, Room 4.05B
1:00	1:00 360° Photos and Videos.. Ian Anderson S02 Webb Centre, 4.02F
	1:00 Workshop: Adobe Character Animator S02 Webb Centre, 3.13
	1:00 Workshop: Wayfinding in Playable Cities Troy Innocent S02 Webb Centre, 4.02D
2:00	2:00 Papers Track S02 Webb Centre, 4.02E
	2:00 Workshop: Adobe Dimension S02 Webb Centre, 3.13
3:00	3:15 Conference Close - S02 Webb Centre, Room 4.02F
4:00	

Keynotes

11:00 Wednesday - S05 QCA Lecture Theatre, Room 2.04

Dr. Gary Grant

Dr. Gary Grant is the Deputy Head (Learning and Teaching) in the School of Pharmacy at Griffith University, teaching pharmacology and pharmacotherapeutics across the Health Group. He successfully completed a PhD from the University of Port Elizabeth South Africa specialising in Medicinal Chemistry and Cellular Biology in 2003, and in 2010 Grant completed a Graduate Certificate in Higher Education that sparked a passion for learning and teaching innovation.

His scholarship of learning and teaching now focuses on capturing a virtual walk-through of a patient's journey through the healthcare system. His practice incorporates the use of panoramic images coupled with mixed-reality, 'choose your own adventure' simulation, and gamification. In 2017 he was awarded a Group Learning and Teaching Citation for innovative and engaging activities. Dr Grant has been able to develop a range of innovative learning and teaching resources to support student learning in health disciplines through effective cross discipline collaboration.

11:00 Thursday - S08 Griffith Film School, Room 2.14

Dr. Troy Innocent

Troy Innocent is an artist, academic, designer and educator whose hybrid practice traverses multiple disciplines. His public art practice incorporates pervasive game design, augmented reality, and urban design supporting a long-term investigation into interactive and speculative experiences of the city as an emergent process.

In 2017 Innocent was awarded the Melbourne Knowledge Fellowship to research and develop playable cities in the UK and Europe leading to a crossdisciplinary collaboration with urban designers, policy makers and creative facilitators to transform the city through play. This approach is also central to his public art practice through 'urban codemaking' – a system he developed for situating play in cities such as Melbourne, Istanbul, Sydney and Hong Kong. Innocent teaches pervasive game design at Swinburne University; and is represented by Anna Pappas Gallery.

11:00 Friday - S02 Webb Centre, Room 4.02F

Dr. Tim Kitchen

With over twenty years of teaching and education leadership experience in Melbourne, Dr Tim Kitchen is currently Adobe's Senior Education Specialist for Asia Pacific. Tim regularly liaises with government officials, schools, universities, Adobe partner companies and organisations with a focus on enhancing creativity in education. He also manages the Adobe Education leadership and active use programs throughout Australasia and supports the professional learning activities within the Adobe Education Exchange (h\ps://edex.adobe.com) which now has over 430,000 members. A passionate advocate for creativity in education, and a well-recognised education thought leader in Australia, Tim is a regular writer and presenter for a wide range of national and international journals and conferences.

Exhibition

Contemporary creative practice across the art and design disciplines are increasingly exploring the intersection of digital technology, virtual experience, and the physical world. This ranges from the use of handheld devices, to AR and VR, to projection installations, and beyond.

The ***Creativity on the Move*** exhibition brings together a variety of works from Brisbane-based practitioners. Some are installations; some are performances; some are screen-based works. In additions, we're pleased to be hosting several works by postgraduate research students in the Digital + Media program at the Rhode Island School of Design, one of the US' premier digital arts courses. These works are shown in video representation.

Several works will be on display in on the 4th level of the Webb Centre, in the midst of the conference, throughout the duration of CreateWorld. In addition there will be an informal reception and performance event Wednesday 29 November 3:30-4:30, during which several temporal and mobile works will be on view.

In addition to the conference exhibition, we would like the delegates to be aware of Phoebe MacDonald's solo exhibition, ***Happy Medium***, in the Project Gallery on level 2 of the Webb Centre. This show of sculptural works highlights the use of both digital and physical processes in a way that is deeply relevant to CreateWorld's concerns.

Performance

2:30 Wednesday - S02 Webb Centre, Room 4.02F

Mobile Listening: Augmenting Environments and Connecting Communities with Sound

Dr Leah Barclay, Queensland Conservatorium Research Centre, Griffith University

Sound has a profound ability to make us feel present and connected to our surrounding environment. Recent years have seen a proliferation of site-specific audio works exploring the possibilities of mobile technologies and locative media in place. This means at any given moment in an urban environment, we could be moving through a sound field of voices, music, memories and sonic art dispersed invisibly throughout the places with inhabit. While this material is available only to those with mobile devices and knowledge of the locative experiences, the advancement of new technologies and the accessibility of mobile devices means this field presents new opportunities for exploring our social, cultural and ecological environments through sound.

In the 2007 CreateWorld keynote, pioneering media artist Nora Farrell remarked that the future of computing is in the mobile phone. She believed it was the most valuable platform to focus our energies as creative artists. As locative media and augmented reality audio shifts into mainstream culture, she was clearly correct. This presentation traces creative explorations with locative sound stretching across a decade of practice at the Queensland Conservatorium Research Centre, all inspired by the innovative work of Nora Farrell and composer William Duckworth.

Beginning with the ground breaking work iOrpheus – an iPod Opera conceived by Duckworth and Farrell – this research explores the impact of iPods, iPhones and iPads across six interconnected projects. Ranging from the first live performance with iPads in remote Australia to spatial sound walks in Times Square and augmented reality audio on the Eiffel Tower – these creative works draw on sound walking, mobile technologies and locative media to investigate the role of sound in achieving presence and connection to place and communities. This presentation highlights the legacy of Nora Farrell's creative and technical innovation and explores the value of mobile technologies in understanding and interrogating our relationship with places and communities through sound.

4:30 Wednesday - S02 Webb Centre, Room 4.02ti

iOrpheus Reflections (Panel and Performance)

In August 2007, New York based composer William Duckworth and pioneering media artist Nora Farrell worked with the Queensland Conservatorium Research Centre on a Fulbright Senior Specialist Grant to create a world premiere of iOrpheus, a ground breaking iPod Opera merging podcasts with live music, dance, installation, fire and a mobile sound garden in the South Bank Parklands. The project re-enacted the story of the mythical musician Orpheus in five acts across various locations in South Bank Parklands with audiences shifting between environments as the immersive story unfolded through interdisciplinary installations and performance.

As the Queensland Conservatorium Research Centre embarks on a documentation project to map the impact of this innovative work over the last decade, this panel and performance reflects on the legacy of iOrpheus with a participatory sound walk on mobile phones and site-specific performance in South Bank Parklands.

iOrpheus Reflections celebrates the life and work Nora Farrell, who sadly passed away in 2017.

To participate in the sound walk and performance, please download the free app AURALITY to your device (iOS and Android).

Papers Track

Each session runs for 20 minutes, with 5 minutes breaks between sessions.

1:00 Wednesday - S02 Webb Centre, Room 4.02ti

1:00 Combining Cooperative Design Patterns to Improve Player Experience

Lachlan Bunker & Reza Ryan

Previous research has identified several cooperative design patterns used to facilitate cooperation in games. The effect that these patterns have on player experience individually had been researched, and it has been found that closely-coupled cooperative design patterns have the greatest effect on player experience. However, no research has yet been done into the effect that combining these patterns can have on player experience. Therefore, this research investigates if combining closely-coupled design patterns can improve player experience. Three patterns were chosen to combine: limited resources, interaction with the same object, and complementarity. A prototype game was made for each combination and participants were asked to play the games, and provide feedback on their experience. The combinations were complementarity and interaction, complementarity and limited resources, interaction and limited resources. Based on the games used in the experiment, the results of combining pa\erns has shown no effect on player experience.

1:25 A Generic Architecture for an Ecosystem of Autonomous Artificial Animals using Dynamic Considerations

Christopher Osmond & Reza Ryan

Using Artificial Intelligence and Non-Player Characters in games has begun to increase rapidly. This is due to both player expectations and availability of new hardware and software technology (Dragert et al, 2012). Artificial Intelligence can increase a player's immersion and experience with a game as the player see realistic and dynamically reacts to occurrences. However, there is a lack of generic design and implementation of Artificial Intelligence systems that employ more complex algorithms that can be easily integrated and scaled. A common example of a scenario that needs a generic Artificial Intelligence system is an ecosystem of autonomous artificial animals. This research aims to design and implement this system for a simulated virtual forest environment that resembles forest wildlife. This system will employ the Utility AI theory and dynamic considerations to create an ecosystem of autonomous artificial animals. The generic structure makes us enable to scale up our system easily by adding more species in the forest with minimum changes. This design for this system will be shown as well as a walkthrough of the implementation of the system in Unity3D.

1:50 Repurposing Augmented Reality Browsers for Acts of Creative Subversion on the Move

David Sargent

Consumer facing Augmented Reality (AR) technology offers innovative new ways for consumers to engage and interact with brands and products via interactive advertising and experiences. Conversely, this technology also creates new channels that can be exploited and subverted by those who wish to generate critical reflection of consumerist culture. This paper aims to highlight that consumer AR technology presents new and unique opportunities for activists interested in subversive communication.

2:15 Complete Cinematic-style Immersion: Improving Interactive Music Soundtrack Design for the Dungeons and Dragons Table-top Roleplaying Game

Michael Drew & Ross McLennan

Traditional table-top roleplaying games offer a more agile, imaginative and physical experience than video games. The table-top roleplaying game, Dungeons and Dragons, has been popular since its creation in 1974 by American game designers, Gary Gygax and Dave Arneson. The game involves player's roleplaying characters while the Dungeon Master (or DM) describes the game's world, its narrative and controls destiny with a set of many-sided di. In recent years, DM's have been attempting to seamlessly integrate sound effects and music into the gameplay to create a more cinematic experience for the character players. This paper explores the efficacy of these attempts and suggests an improved method for the creation and control of interactive music to enhance cinematic-style immersion during gameplay. Utilising Apple's Logic Pro software to explore conventions of film and game music composition and Audiokinetic's WWise audio middleware for integration into game engines like Unity and Unreal, a final prototype iPhone app will be demonstrated. This prototype has the potential to greatly enhance the Dungeons and Dragons game experience, but also has the capacity to be incorporated into myriad other table-top roleplaying games that exist on the market.

2:40 Millennials, Politics & Visual Communication

Rae Cooper

There is a growing decline in political engagement amongst young Australian voters. Simultaneously, we have a growing number of digital platforms designed to assist voters in making choices, understanding their preferences and ultimately – who to vote for. This paper explores a shift in response to the issue of political apathy, through the design of a new online platform. By moving the focus from political science to visual communication design, this new concept aims to engage a contemporary understanding of design activism as a mechanism of political empowerment.

9:00 Thursday - S02 Webb Centre, Room 4.02ti

9:00 Island Healing: A Global Exploration of Sound Healing Ideas and Practices and the Implementation of These Into Music Intended To Make Peace With Place

Clara Durbridge & Ross McLennan

Sound and music have been linked to healing since early civilisation. Likewise, in modern time's studies demonstrate sound and music as effective methods in decreasing anxiety, accelerated heart rates and blood pressure. The aim of this paper is not to prove or disprove the efficacy of sound as a healing agent, but to define and explore sound healing as a relatively new field of study, and then to incorporate its ideas, techniques and instruments into an original music composition intended to heal, through sonic metaphor, the damaged natural world. The paper documents a journey from one side of the Earth to the other – with nothing but an iPhone – to capture and record the concepts and practices of modern and ancient sound healing. The paper culminates in the incorporation of these ideas and practices into original music created within Apple's flagship music software, Logic Pro X. It is anticipated that this study and its resulting music will inspire other composers and artists who are seeking to experiment with their own creative practice and possibly incorporate aspects of sound healing into their own work.

9:25 Using Technology-based Devices to Boost Motivation when Lettering by Hand

Elizabeth Reed & Dominique Falla

An auto-ethnographic perspective on using technology-based devices to boost motivation when lettering by hand. To learn or to improve skills surrounding cursive handwriting, one needs to practice the letterforms. To produce these letterforms we need to build muscle memory, and the best way to do this is using repetition. The standard method of repetition is to repeat the same letterform over and over again—for example repeating a page of A's and B's and so on. This method of learning, although useful, has the potential to lose the interest of the learner. By using multiple sensory activities and project-based learning, one can be motivated to complete, the otherwise mundane act of repetition. Practice and repetition are necessary if one is seeking to improve skills when writing by hand. There are many areas, both digital and non-digital, that can be explored to improve the process of handwriting practice. No matter what the activity, if the focus is on learning the movement and the strokes of the letterforms, we can start to play and experiment with a range of different techniques. Emerging technologies using creative apps in virtual reality are an exciting development. There is something engaging about writing with ink- filled nibs across paper fibres, then switching over to virtual reality and writing the same letters on a much larger scale.

9:50 The Real Thing: An Aesthetic Comparison of Modelled Versus Traditional Guitar Amplification Technology in the Studio

Rob Keko & Ross McLennan

Since the rising popularity and widespread commercial use of the electric guitar in the 1950's, advances in guitar amplifier design and technology have played a key role in shaping the soundscape, tonal characteristics, recording methods and production styles of contemporary music. In recent years, digital modelling techniques have created new ways of producing sought after guitar amplifier sounds, which have changed the way producers, artists and guitar players use this technology both in the recording studio and in live performance. This in turn has impacted on how listeners, concert attendees and music consumers hear and experience recordings and live music. Extensive comparisons between authentic and modelled amplification have been conducted in industry magazines.

However, these tend to be simplistic or overtly commercial in nature with typical yes/no style responses. A more rigorous approach is required which ascertains both gut feeling, as well as a more considered aesthetic response to the two technologies. This paper, therefore, presents a comparative study between traditional and modelled guitar technology that contextualises these amplifier sounds within fully produced music. It presents a non-biased quantitative and qualitative study of audience reaction to music – recorded using Apple's Logic Pro X software – which includes both amplification styles: authentic and modelled. The paper concludes with the results of the study and reflects upon the future of guitar amplification.

10:15 Conceptualising Game Design – A Tangible approach to Level Design

Henry Sun & Justin Carter

Conceptualising and communicating game design ideas amongst teams of game developers can be an enigmatic process. Designers of video games often rely on rapid prototyping and iterative approaches to creating game play experiences. Deep and meaningful experiences are not always easily expressed in the form of words and as a result, initial design intentions are often misinterpreted and or poorly communicated. This often leads to designers of games relying on a serendipitous approaches as they intrinsically move toward design intentions. These approaches are largely derived from traditional models of agile software development placing li\le emphasis on the cognitive process of individuals in the development team. Therefore, approaches based in theories of cognition are rarely considered for designers of games. One such area of this field is tangible design which attempts to investigate links between cognitive science and the physical tactile world. The impact that tangible approaches have on collaborative game design is yet to be thoroughly investigated.

This paper describes a practice-led study that aims to test the influence of tactile 3D printed video game assets on cognitive processes and design communication for teams when conceptualising game designs. This is achieved through a review of existing literature in the field, followed by an in depth analyses of a tangible approach to game level design. Through this process the study presents a deeper understanding of the implications that tangible design strategies have on conceptualising and communicating game designs.

10:40 Performance Capture: Split between the Fictitious and Physical World

Joel Bennett & Chris Carter

Performance Capture (PCap) is the process of capturing a continuous recording of an actor's movements and emotions using motion capture technology, typically in a 3D virtual world. This presents a somewhat unique situation for the actor in that they are challenged to imagine their virtual counterparts and a completely abstract, computer-generated world whilst delivering their performance. Central to this paper is the identification of the various implications that affect the actor's abilities during a performance by investigating professionals' experiences when using performance capture and through the exploration of the implications of performance capture in the creation of a short experimental animation.

1:00 Thursday - S02 Webb Centre, Room 4.02ti

1:00 Early Development of a Flexible Procedural Approach to Automatic Jazz Improvisation

Daniel Field

This paper describes early work on an approach to automatic improvisation in the jazz idiom, derived from analysis of human practice, with algorithm development in the Jython Environment for Music (JEM). From the outset this project sought to be inspired by the human process of jazz improvisation and to apply as directly as possible the logic and processes of a human engaged in the activity of jazz improvisation – without necessarily using any specific computing technique or algorithm class. This paper describes the thinking and early experimentation leading to the current prototype version which improvises essentially in real-time and demonstrates how the use of variable parameters can greatly increase the flexibility of procedural programming.

1:25 Crafting Environment Narrative: Investigating Environmental Storytelling use in Video Game Narrative

Blair Findlay & Justin Carter

Environmental storytelling has become a useful tool in game design as it can be employed in different ways depending on the designer's needs. The use of these techniques while documented aren't described clearly for a designer to easily incorporate into their game designs. This paper explores environmental storytelling and its utilisation in games with the knowledge translated into the design and creation of principles to serve as the means of answering the needs of beginning designers.

1:50 An Autonomous Music Composer based on Affective Principles

Jacob Olander

Over the past 60 years, there has been much research into the field of algorithmic composition. Techniques have been refined, and processes developed to suit a variety of needs. Recently however, focus has been turned to algorithmic composition for more emotive purposes. Affective Algorithmic Composition (AAC), the product of this research is a rapidly developing field, with many potential applications. In particular, AAC has the potential to solve one of the most prevalent issues in game audio. This research described in this paper covers the implementation of an Affective Algorithmic Composition system into a computer game. The methodology used is based upon Design Science Principles and has a pragmatist theoretical perspective. Using Lindenmayer Systems and Markov chain theory, a fully functional system will be developed.

2:15 Visual Representation – Examining Level of Abstraction and Game Play Sensation

Stevie Mills & Justin Carter

Visual representation for video games describes the way in which objects are displayed in order to convey meaning and recognition for the player. As a component of the games metaphor, visual representation offers context for interaction and provides players with meaning for their actions. A key component of visual representation is how closely the representation resembles real objects. If the representation establishes full resemblance it is considered realistic. However, if it does not attempt to resemble or provide meaning for the object it is considered abstract. Early generation game systems provided low fidelity graphical capabilities and therefore designers were restricted in the level of realism that could be achieved. With the introduction of each new generation of game systems, capability to achieve more realistic fidelity in representations has increased expanding the spectrum of possibility between real and abstract. This notion of varying levels of abstraction linked to interaction has implications for designers of video games a\empting to achieve specific gameplay sensations. Tensions arise for player sensation when the level of abstraction fails to the match the player's expected preconception of the game's play mechanics, creating a dissonance between player and the game play experience.

This paper outlines the results of a practice-led study examining visual representation as a component of game design. This is achieved through the development of a prototype that provides opportunity to explore varying levels of abstraction within specific rule based contexts. The study illuminates links between how meaning is conveyed visually to a player and the implications this has for game play sensation.

2:40 Plugins, Presets and Practice: The Impact of Digital Technologies on Contemporary Music Production Processes and the Music Industry

Andy Aubun & Ross McLennan

Mobile devices have not only changed the way we purchase and listen to music, but are changing the way song writers, composers and producers create. Mobile applications and laptop computers allow composers the freedom to make music anywhere, implementing a myriad of music making apps, software programs and plug-ins designed to simplify and, therefore, democratise music creation. The previously vast and complex arts of music composition and production are now accessible to everyone and accordingly, traditional methods of music composition and production are no longer standard practice. This paper explores these new standard methods of composition and production through the creation of a commercial song. Using iPhone applications for conceptualising and refining the song, computer-based methods for recording and production using a Macbook Pro laptop, and the Internet for automated mastering, this paper illuminates and catalogues a new standard in creative practice, and redefines traditional roles such as music composer, music producer and sound engineer.

3:30 Thursday - S02 Webb Centre, Room 4.02ti

3:30 Generating a Virtual Forest Environment Using Procedural Content Generation

Liam Potter & Reza Ryan

Video game worlds are growing rapidly, creating a large amount of content that digital artists need to produce. To cope with this amount of content, game development companies would have to hire more artists and content creators, which is not economical. Therefore, Procedural content generation (PCG) techniques have quickly become a key area in the development of video game worlds. These techniques can be applied to generate a wide variety of things, from entire forests to the individual leaves on a tree. Simulated real-time virtual forests are one of the more common and complex virtual environments in contemporary video games that have to be generated procedurally. In this research, we developed a system that integrates different PCG techniques to automatically generate and simulate a virtual forest in real-time. These techniques include Height Generation, Terrain Texture Generation, Detail Generation, Point Generation, Shadow Map Generation, Life Cycle Simulation and Day/Night Simulation. The implemented day/night system accurately calculate angle of the sun through the time of day to simulate life cycles of all flora in the environment in real-time. The optimized developed system can be easily integrated with any real-time game that requires a forest environment.

3:55 Exploring the Craft of Immersion in Virtual Reality

Shanice Hayes & Justin Carter

Virtual reality (VR) systems are increasingly utilised as a medium in which to experience video games. These systems incorporate technology that is designed to offer the user an experience of a simulated physical presence within a virtual environment. The acceptance of VR as a platform for gaming has given rise to many new challenges for designers of games. These new challenges represent a disruption in the craft of game design on a scale not experienced since the transition from 2D to 3D graphics. This paper offers insight into the challenges for designers of VR games through the examination of existing strategies and design principles. These principles are then applied in the construction of a creative work that further expounds techniques for practitioners creating VR games.

4:20 Approaches to Modular Construction for Real-Time Game Environments

Braiden Fenech & Justin Carter

Video Game design and development has evolved into a profitable and widely accepted creative field that operates within ever-increasing technical capability. This improved capability has facilitated an increase in the visual fidelity achievable within real-time environments. Game artists faced with creating these environments are tasked with maximising both system resource allocation and efficiency in production time. One strategy that has been adopted by artists is to implement a modular design and construction approach when developing environmental elements. Although this approach offers many benefits for artists, the associated skills and techniques are not well defined.

Through an exploration of existing literature and reflection on current practice, this study identifies and evaluates a range of contemporary approaches to modular construction for real-time environments and in the process offers valuable insight for practitioners.

2:00 Friday - S02 Webb Centre, Room 4.02ti

2:00 Capturing Willandra ; Challenges & Experiences Bringing a Hidden Historical Site to Interactive Digital Life

Chris Little & Dale Patterson

The Willandra trackways are one of Australia’s most important historical sites. They include the footprints of our earliest Australians, some 20,000 years old, and all captured in the clay-pans of the Willandra lakes region. Unfortunately these national treasures are hidden, for their own protection, beneath a layer of sand and thus are completely unavailable to the broader public. This paper discusses the challenges in using digital capture techniques to capture and convert this data into interactive experience.

2:25 Unreal Realities: Non-Photorealistic Rendering in Virtual Reality

Peter Mills & Justin Carter

Virtual Reality (VR) is a rapidly growing field, disrupting many industries, such as video games, engineering, architecture, and medical visualization. Designing VR experiences involves the use of digital technology and rendered 3D graphics to create immersive virtual environments. While traditional user interfaces require users to view and interact with a screen, VR places the user inside a virtual environment through the use of a head mounted display (HMD). This form of user interface has implications on how rendered graphics are perceived and interpreted. One rendering technique used extensively in design and construction of virtual environments is Non-Photorealistic Rendering (NPR). NPR is primarily concerned with providing opportunity for a wide variety of expressive rendering styles such as toon, hatching and outline shaders.

This paper examines Non-Photorealistic Rendering techniques for virtual reality experiences, specifically focusing on strategies applied to achieve characteristics of toon, hatching and outline shaders, in virtual reality contexts. Through first identifying the common features traditionally used for NPR and then reconstructing these features in a virtual reality context the project illuminates unique considerations for practitioners implementing NPR effects in VR.

2:50 Design and Production of a Customisable 3D Character Pipeline

Matt McRae & Reza Ryan

One of the major barriers in creating a customisable 3D character is the lack of knowledge into the creative and technical pipeline required. Most games that have these kinds of systems are high budget games, with the artists and programmers having lifetime’s worth of experience. These systems are also highly valued, and as such are often proprietary in nature, which means very li\le information on the actual construction is readily available. This research project aims to design a pipeline for creating a base character mesh tor single mesh to be used in a character creation system.

Presentations Track

1:00 Wednesday - S02 Webb Centre, Room 4.02F

Augmented Reality in Education – A Brief History

Stephen Atherton, Bond University

In 2016 "Pokemon Go" not only grabbed the attention of the public and the press – it injected a new life into a mature yet quickly evolving technology. In June this year Apple's ARkit was released and it has hit the reset button by empowered developers to head in new directions and do so with a minimum of development effort.

This session will look at the evolution of AR by showing examples of work that has been done in multiple disciplines from various universities. The talk will review the scholarly literature and examine the efficacy of AR as a teaching tool and should offer a basic background for the more in depth and technical AR presentations and workshops at the conference.

1:45 Wednesday - S02 Webb Centre, Room 4.02F

Using Virtual Manipulative (VM) Apps to Build Basic Circuit-building Procedural and Conceptual Knowledge in Young Children

Garry Falloon, Macquarie University

The use of virtual manipulatives (VMs) has been relatively commonplace in mathematics education for many years, yet their use for science learning has been less frequent, and generally limited to virtual laboratories or simulations used to support specific investigations or experiments, or 'make visible' to students difficult to grasp or experience scientific phenomena. However, with the advent of low cost mobile devices and an array of science-focused apps, there is an opportunity to leverage the potential of VMs to introduce students to abstract and practical science ideas at a younger age.

This presentation outlines stage 1 of a study undertaken with new entrant children (5 year olds) in New Zealand, where a range of VM apps were used to introduce simple electrical circuit-building procedures and electricity concepts. Stage 2 of the project investigated whether or not the children could transfer any knowledge developed using the VMs into practical circuit building tasks using real equipment.

The teaching component of the study followed a guided discovery approach that provided minimal initial teacher direction. 'Can You?' circuit-building challenges were used to introduce different circuit types and concepts, and engage the children in each of the five, 40-minute teaching and research sessions. Empirical data was collected using an iPad display recorder app, and analysed for evidence of procedure and concept knowledge-building related to circuit construction, the function of circuit components, and 'what happens' in a circuit (ie., current flow, resistance etc.).

This presentation will share outcomes from stage 1 of the study that suggests VM apps may provide teachers with a useful resource to build basic electricity concepts in early years education. It will present and discuss illustrative data highlighting how the students used the VMs to build understanding of different circuit designs and components, and how current was controlled.

2:30 Wednesday - S02 Webb Centre, Room 4.02F

Mobile Listening: Augmenting Environments and Connecting Communities with Sound

Dr Leah Barclay, Queensland Conservatorium Research Centre, Griffith University

See the Performance notes on page 9.

9:30 Friday - S02 Webb Centre, Room 4.02F

State of the AR

Iain Anderson, Training Brisbane

Apple's new ARKit has launched to some fanfare with iOS 11, and some flashy demos are already available. But is Augmented Reality just another fad? In this presentation, gain a broad overview of what AR is, of what developers have done so far with AR in gaming, education and art, and what it's likely to be used for next.

Attend if you've heard of AR but not really seen it in person, or if you're on the hunt for how you could potentially use AR in your own classrooms.

10:15 Friday - S02 Webb Centre, Room 4.02F

Mix Your World with Holograms

Thomas Verbeek, 8i Limited

Holo is an augmented reality app that brings realistic, 3D holograms to the masses. It allows users to manipulate volumetric media on their mobile devices using state-of-the-art rendering technology by 8i. Enabling this experience naturally comes with a lot of challenges, ranging from mobile device resource restrictions to explorations in user experience to being ready on the App Store for the worldwide release of ARKit.

This presentation explores some of the challenges we encountered and overcame during the development and release of Holo for iOS. We discuss some of the early assumptions and opportunities that guided the product to its initial release; evaluate design challenges regarding discoverability and interaction; provide an under-the-hood look at how we incorporated ARKit into Holo and shed insight into the future of 8i's technology.

1:00 Friday - S02 Webb Centre, Room 4.02F

360° Photos and Videos – Fad or Future?

Iain Anderson, Training Brisbane

Today's 360° photo and video techniques let you capture the whole world around you, and today's VR goggles and smartphones let you see whatever part of the world you want to look at. This presentation will show you some basic techniques on how to capture and edit photos and videos in 360° formats, and how to distribute them to a wide audience. We'll use cheap cameras and widely available software, and you can make your own call on whether this is the way of the future or another fad.

Workshops

9:00 Thursday - S02 Webb Centre, Room 3.07 Mac Lab

Unity and ARKit

Scott Roberts

ARKit is set to be available for 400 million iOS devices this year, making it the largest immersive technology platform in the world. We've seen a multitude of examples demonstrating how ARKit is helping developers create some impressive augmented reality apps, from virtual tape measures and navigation to fun things like games. It's now time we see creatives from all disciplines employing the technology to blend virtual environments with real ones. This workshop will explore the pathway to get you set up with ARKit in Unity, including plane detection, raycasting, and hit testing. Begin your immersive explorations with a taste of AR in Unity.

1:00 Thursday - S02 Webb Centre, 4.02ti

Teaching Coding on the iPad

Jonathan Sagorin

Are you facing the choice of how to teach or support coding on the iPad, and don't know where to get started? Or are you just interested yourself, and want to learn moret? This workshop is for you! We'll cover three popular offerings: Swift Playgrounds (from Apple), Codea (from Adelaide-based Two Lives Left), and Pythonista (from OMZ Software).

We'll evaluate each app using the same selection framework, which you can use to choose any eduction app appropriate to your needs. We'll look into main features of each, getting started with simple coding, how to get additional content and share code with others, and where to find the best support resources.

Note: this is a hands-on ***three-hour*** workshop which requires that you bring an iPad along with you, running iOS 10.3 or iOS 11. All apps are available from the iOS App Store, and we encourage you to install them ahead of the conference to save time. Note that the combined size of all three downloads is around 900 megabytes.

1:00 Thursday - S02 Webb Centre, 4.02C

Adobe Draw + Capture

Adobe Staff

Draw puts your favorite vector drawing tools and features into a simple, modern interface so it's easy to turn any idea or inspiration into a gorgeous design. You can even launch Adobe Capture CC from within the app, create a new shape, and have it immediately appear on your Draw canvas.

2:00 Thursday - S02 Webb Centre, 4.02C

Adobe Premiere Clip

Adobe Staff

Turn the clips you shoot with your Android or iOS device into videos that look and sound incredible. Then share them on your favorite social channels, or sync them to Adobe Creative Cloud to take them further in Premiere Pro CC.

3:30 Thursday - S02 Webb Centre, Room 3.07 Mac Lab

Adobe XD

Adobe Staff

Go from concept to prototype faster with Adobe XD, the all-in-one UX/UI solution for designing websites, mobile apps, and more. With smooth, powerful performance, it's easy to deliver experiences that work and feel as good as they look on any screen.

9:00 Friday - S02 Webb Centre, Room 4.02C

TouchDesigner; Audio-reactive Visuals for Performance

Jason Haggerty

Join Jason in creating audio-reactive visuals and a custom made control-panel in the procedural programming platform, TouchDesigner. Perfect for artists, developers, and all kinds of tinkerers, TouchDesigner allows for very flexible programming from user-interfaces and complex real-time geometry, to data visualisation and interactive environments.

1:00 Friday - S02 Webb Centre, 4.02ti

Wayfinding in Playable Cities

Troy Innocent, Swinburne University of Technology

Cities can be sites for self-discovery and transformation; they are also constantly in the process of becoming. Urban Codemaking is a framework for decoding and reimagining cities, a programming language for urban space that marks locations in the city using codes enabling multiple alternate readings of that city – by machines, humans, and other entities.

This workshop will invite feedback on the current iteration of this system following a series of interventions into public space situated around experimental and playful approaches to wayfinding using urban codes.

For the best experience with this workshop, you should bring along an iPad running iOS 11.

1:00 Friday - S02 Webb Centre, Room 3.13 PC Lab

Adobe Character Animator

Adobe Staff

Create a 2D character and make it come alive. Character Animator CC copies your facial movements so your characters act — and react — realistically.

2:00 Friday - S02 Webb Centre, Room 3.13 PC Lab

Adobe Dimension

Adobe Staff

Adobe Dimension CC (formerly Project Felix) makes it easy for graphic designers to create high-quality, photorealistic 3D images. Composite 2D and 3D assets to build product shots, scene visualizations, and abstract art.

General Information

Registration Desk

The registration desk will be based near the entrance to S05 QCA Lecture Theatre on the opening morning of the conference, and will relocate to S02 Webb Centre, Room 4.05A for the remainder of the conference.

Meals & Refreshments

Start-of-day refreshments, **lunch and afternoon tea each day** will be served in S03 (Webb Centre) on level 4, in room 4.05B.

The **conference dinner** will be held on Thursday night at the Ship Inn, a short walk from the S07 (The Graduate Centre). Spaces are limited to people who indicated they would be attending at the time of registration.

Caterers have been provided with special dietary requirements as specified by delegates at registration time. Please understand that it may be impossible for caterers to address any special requirements not notified at least 7 days in advance of the event.

Please note that QCafé in the Grey St. Studios building is privately owned and operated, and not part of the catering for CreateWorld. You are welcome to purchase food and beverages at your own cost.

Internet Access

Wireless internet access is available and access details will be provided at registration time. If you are from an institution that supports **Eduroam**, you can use your originating institution credentials to connect.

Emergency Contacts

QCA Campus Security - dial 7777 (from internal telephones) or call 3735 6226.

For all emergencies, call triple zero, 000 or 112. Most mobile phones will call 000 (for Emergency Services) even when no credit is on the SIM card.

Conference Contacts

Tony Gray - 0432 018 441
Daniel Della-Bosca - 0419 735 095
Seth Eillis - 0490 220 740

Partners

We couldn't host CreateWorld without the generous support of a number of people and businesses.

We extend our thanks to Dr. Tim Kitchen, Jane Chen and Jerry Wong from Adobe for their support and for running workshops on Adobe's latest Creative Cloud products.

Thanks to the extraordinary team from The Queensland College of Art (QCA), a specialist arts and design College founded in 1881, and the oldest arts institution in Australia. The South Bank facility comprises public exhibition spaces, a cinema, conference rooms, a multimedia art gallery and the most modern and versatile studio facilities in Australia.

And thanks to Griffith University, our long term event partner. Griffith University was created to be a different kind of university—challenging conventions, responding to trends and pioneering solutions. Ranking in the top three per cent of universities worldwide, its future-focused degrees are developed in consultation with industry, based on cutting-edge research, and taught by Australia's most awarded teachers.

Conference Chairs

Daniel Della-Bosca is a lecturer in fine art, design and interactive media at the Queensland College of Art, Griffith University. He has worked and exhibited nationally and internationally as a designer and artist and is committed to the advancement of art and design education. Daniel's primary research focus is the application of fractal mathematics to the field of aesthetics, and his specific skillsets are the interdisciplinary bridges between art, design, CAD software and algorithmic generation of image and form. Daniel has a portfolio that spans public sculpture, exhibit design, jewellery and animation, all for the purpose of engaging in visual and haptic discourse.

Seth Eillis is senior lecturer in interactive media program at the Queensland College of Art, Griffith University, where he is program director of the Bachelor in Creative and Interactive Media. He is a narrative artist and interface designer; his work draws upon local history, allegorical narrative, and experience design to create stories both historical and fictional in new, experiential forms. Seth as worked with local museums and galleries on their collections and exhibitions; his own projects have shown in galleries, streets, symposia and festivals throughout the U.S. and Europe, and at a few places in the Atlantic Ocean.

Dr. Dale Patterson is a computer scientist and lecturer in Digital Design, Visualization and Interaction. Dale has worked in the field of computer science both commercially, in Education and research for more than 20 years (focusing on 3D computer graphics and its applications). Dale's primary areas of interest include human computer interface design, VR & AR, 3D computer animation, visual effects and games. Dale also has strong research interests in computing as applied in bio-medical applications (e.g., scientific visualization, applied games & learning, artificial intelligence).

Tony Gray has been Chair of the AUC since late 2010. He is a software developer and educator with over 25 years of experience providing IT support in the University sector, and is co-chair of the AUC's other two conferences–/dev/world for software developers and X World for system administrators. Tony also writes for O'Reilly Media on the Swift programming language.

About the AUC

The AUC was established towards the end of 1984 as a partnership between Apple Computer and nine Australian universities.

At the heart of the relationship was the ability for departments, staff and students to obtain Apple technology at reduced prices and to enable the development of innovative solutions using the Macintosh. The AUC grew to form a network of educational technologists across the universities of Australia and New Zealand, growing to 37 member universities by 2012.

The history of the AUC is one of adapting to change, and in 2013 we reinvented ourselves as a not-for-profit association with no formal relationship with Apple. Our mission is to support and build communities around the use of Apple technologies by sharing experience, insights and know-how amongst members, developing people as leaders, and inspiring and fostering innovative use of technology.

Each year, we hold three conference events for specific subsets of our community. **X World** is for system administrators and support staff, **CreateWorld** is for performance artists, teachers, and those working in the creative spaces, and **/dev/world** is for software developers. Our conferences are open to all.

Learn more, including how to become a member, at https://auc.edu.au

Complete Papers

Combining Cooperative Design Patterns to Improve Player Experience

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Abstract
Previous research has identified several cooperative design patterns used to facilitate cooperation in games. The effect that these patterns have on player experience individually has been researched, and it has been found that closely-coupled cooperative design patterns have the greatest effect on player experience. However, no research has yet been done into the effect that combining these patterns can have on player experience. This research, therefore, investigates if combining closely-coupled design patterns can improve player experience. Three patterns were chosen to combine: limited resources, interaction with the same object, and complementarity. A prototype game was made for each combination and participants were asked to play the games, and provide feedback on their experience. Based on the interaction in the developed games, and the simplicity of their design, in general, combining the selected patterns has shown no effect on player experience, with the exception of the level of engagement for the interaction with the same object and limited resources combination.

Keywords
Cooperative design patterns, Cooperative games, Closely-coupled interaction, Collaboration, Cooperation, Game design

Introduction
Lots of research has been done into the area of cooperative games and cooperative design (Beznosyk, A., Quax, P. Lamotte, W., Coninx, K., 2012a; Beznosyk, A., Quax, P. Lamotte, W., Coninx, K., 2012b; Ducheneaut, N. & Moore, R. J., 2004; El-Nasr et al., 2010; Ewoldsen et al., 2012). Cooperative games focus on encouraging collaboration and team work, with the ultimate goal being the collective victory of everyone playing (El-Nasr et al., 2010), while cooperative design involves the design of different cooperative patterns and outlining how to make cooperative games. Undoubtedly one of the major findings in the area of cooperative design is the identification and application of several different design patterns for making cooperative games. A study by El-Nasr et al. (2010) identified 13 cooperative design patterns that are used to facilitate and encourage cooperation in games. The effect that these patterns have on player experience (such as player enjoyment, or the level of cooperation between players) has been investigated. However, Beznosyk et al. (2012b) suggest that researching an effective way of combining these patterns could be of great value to game designers.

This research aims to study how these patterns can be combined, and the effect that combining these patterns has on player experience. Beznosyk et al. (2012b) found that closely-coupled design pattern have the greatest effect on player experience , so the three closely-coupled patterns investigated by Beznosyk were chosen for this research. These patterns are limited resources, interaction with the same object, and complementarity. Limited resources relates to restricting resources to encourage sharing between players; interaction with the same object provides objects that all players can manipulate; and complementarity involves player roles that complement each other. For each pair of patterns, a prototype game will be developed, implementing the combination. The prototypes will be play-tested by volunteers to identify the effect that each combination has on player experience. The data from the volunteers will then be compared to the results from single-pattern games, to determine if combining the patterns improves player experience, and demonstrate potential ways of combining the selected patterns, which Beznosyk et al. (2012b) suggests could be of significant value to game designers. Knowing how these patterns can be combined, and which patterns work best together can help designers create more enjoyable player experiences.

Related Work

Collaborative Games
In traditional game theory, there are two main categories for games, competitive games and cooperative games (Zagal, Rick, Hsi, 2006). According to Zagal et al., competitive games are games where player's goals are opposed, and which "require players to form strategies that directly oppose the other players in the game", citing Chess and Checkers as examples of this category of game (Zagal, 2006). John Nash describes cooperative games as "situations involving two individuals whose interests are neither completely opposed nor completely coincident", but which encourage participants to "discuss the situation, and agree on a rational joint plan of action" (Nash, 1953). Zagal et al. claims, however, that a third category exists, collaborative games. "In a collaborative game, all the participants work together as a team, sharing the payoffs and outcomes; if the team wins or loses, everyone wins or loses" (Zagal, 2006). They state that competitive and collaborative games lie at either end of a spectrum, with cooperative games in the middle. Zagal et al. argue that, while appearing collaborative in nature, cooperative games often reward strategic, competitive behaviour, such as free riding and backstabbing, and such, "the best strategy in a cooperative game is knowing when to behave competitively" (Zagal, 2006).

Cooperative Design Patterns
One of the main studies into cooperative design patterns was done by El-Nasr et al. (2010). A previous study identified 6 design patterns, and El-Nasr et al. (2010) extended this study. By analysing a selection of 14 cooperative multiplayer

games such as Left4Dead (Valve, 2008), Lego Star Wars (Traveller's Tales, 2005), and Beautiful Katamari (Namco Bandai, 2007), El-Nasr et al. developed an initial list of design patterns. This list was reviewed and approved by an independent researcher with over 10 years of experience in the games industry. El-Nasr et al. then asked a team of two independent researchers to play the selected games and develop their own list of design patterns. The independent researchers identified the same patterns as El-Nasr et al., using slightly different terms for some of the patterns. The two teams then met to discuss the patterns, and the final set is:

Complementarity, which involves players using character roles that complement each other. An example of this is in Lego Marvel Superheroes (Traveller's Tales, 2013), where players will frequently encounter obstacles that only one character can overcome, and players must use the corresponding character to enable the whole party to proceed.

Synergy between abilities, where one character can change or assist the abilities of another. This pattern is shown in World of Warcraft (Blizzard, 2004), where Shadow Priests can make an enemy vulnerable to shadow damage, which also increases the damage Warlock's can cause to that enemy.

Abilities that can only be used on another player, which involves restricting player abilities like healing, shooting, or shielding so they only work on other players, for example, medics that can heal other players, but not themselves, as seen in Team Fortress 2 (Valve, 2007)

Shared goals, where a group of players are given a single quest with a shared goal, a pattern used in massively multiplayer online games (MMOs) like World of Warcraft.

Synergies between goals, which encourages players to cooperate through synchronised goals. An example of this is in Team Fortress 2, where one class, the pyro, has an achievement that requires them to burn enemies while ubercharged (made invulnerable) by another class, the medic. The medic has a matching goal to ubercharge a pyro while they burn enemies.

Special rules, which are rules that can change how certain actions affect cooperating players. An example of this is friendly fire, where players accidentally shoot members of their own team. Special rules would stop the player being shot at from getting hurt by members of their team.

Camera setting, or how the camera is displayed, and how player movement affects the camera. Some examples of this are split screen, as seen in Mario Kart 7 (Nintendo, 2011), or all characters in focus, like in Lego Marvel Superheroes.

Interacting with the same object, where the game contains objects that the players can manipulate, such as in Beautiful Katamari(Namco Bandai, 2007), where players share a ball that they can move around.

Shared puzzles, which pertains to puzzles the players must work together to solve. Many examples of this are seen in Lego Marvel Superheroes.

Shared characters, where the players share a pool of characters that they can use. This pattern is utilized in Lego Marvel Superheroes.

Special characters targeting lone wolf, is a pattern that causes non-player characters (NPCs) to target players that work alone. Examples of this pattern are the Hunter and Smoker in Left4Dead (Valve, 2008).

Vocalization, where characters indicate the occurrence of events through vocalizing. This is seen in Left4Dead, where characters will announce objectives, or the arrival of tough enemies.

Limited resources, which encourages players to share resources. This pattern is used in Borderlands (Gearbox, 2009).

To analyse the effectiveness of these patterns, El-Nasr et al. (2010) developed several Cooperative Performance Metrics (CPMs). The metrics are associated with observable events in a play session, and can be used to help annotated a videoed play session. An initial set of metrics were developed by observing a group of the researchers play cooperative games. These metrics were then sent to three industry game designers. Based on their feedback, the research team discussed the metrics, and confirmed a final set of 6 metrics. These are:

Laughter or excitement together, where players expressed verbal or non-verbal enjoyment of the game, for example, laughing at an in-game event, like a cutscene or character dialogue.

Worked out strategies, when players discussed a problem aloud, or divided an area to cover it faster. This is frequently seen in Lego Marvel Superheroes.

Helping each other, where one player assists another with knowledge of the game, or how to pass an obstacle, for example, pointing at what button to press on a controller.

Global strategies, when players take complementary roles to surpass a challenge. An example of this is in Lego Marvel Superheroes, where one player solves a puzzle to progress, and the other player defends them from enemies.

Waited for each other, where the skills or ability of one player causes them to move ahead faster, and need to wait for the other player/s to catch up. This can be seen in Lego Marvel Superheroes, where one player will rush ahead, or solve a puzzle quickly, and need to wait for the other player to catch up.

Got in each others' way, when players want to perform contradicting actions, which interfere with what the other player wants to do. This can be seen in Lego Star Wars(Traveller's Tales, 2005), where two players want to move in opposite directions, but, due to the fixed camera, neither of them are able to.

The Effect of Communication on Cooperative Design

Besnosyk et al. (2012a) extended the research by El Nasr et al.(2010), examining the effect that lack of communication has on player experience. The researchers took 6 of the design patterns identified in the previous study, and developed a game for each one. The patterns they chose were limited resources, complementary, interaction with the same object, shared puzzles, abilities that can be used on other players, and shared goals. The patterns were selected based on their popularity, and frequency of appearing in multiplayer games. They separated these games into two groups based on how closely the players were coupled, and how much the actions of one player affected the other. Limited resources, complementary, and interaction with the same object were defined as being closely-coupled, while shared puzzles, abilities that can be used on other players, and shared goals are loosely-coupled (Beznosyk et al., 2012).

The games were played by 36 volunteers in pairs. The players were paired anonymously and any form of communication was avoided. After playing the games, the participants gave feedback about their experience of each game, and how the lack of communication affected the game. Analysing these results, the researchers found that the closely-coupled design patterns created better player experiences, and were hindered the most by the lack of communication. This study prompted research into analysing and classifying the other cooperative design patterns, as well as investigating the effect that combining these patterns would have.

Another study into cooperative design was done by Ducheneaut and Moore (2004), who examined player interaction in massively multiplayer online games (MMOs), like World of Warcraft, where hundreds of thousands of people play on a daily basis. Using Star Wars Galaxies as an example, they recorded the chat logs in two major social hubs over the course of 26 days. Analysing this data, the researchers noted that most interactions between players were needs-driven, and that there was a distinct lack of social interaction (Ducheneat, 2004). There were some meaningful, person-to-person interactions, however, due to the prevalence of players using macros to advertise their services, it was hard for players to find other people looking for a personal experience. The researchers did note, however, that they only had access to public data, and that there was lots of hidden social activity, such as private messages, and group chats. The researchers concluded this study by suggesting these problems could be fixed through rewarding players for interacting with each other.

The Effect of Cooperative Games on Player Behaviour

A study was conducted by Ewoldsen et al. 2012 into how playing violent games cooperatively affected subsequent player behaviour. They separated 119 participants into 4 groups, direct competition, indirect competition, cooperation, and control, which determined how the participants would interact with each other. The participants played Halo 2 (Bungie, 2004), a competitive shooting game, in pairs, followed by taking part in a social dilemma task. The direct competition group played Halo 2’s multiplayer arena mode, and were told to kill their opponent more times than their opponent killed them. The members of the indirect competition group both played the single player campaign of Halo 2, and were instructed to progress further through the campaign than their partner did. The cooperation group had to work together with their partner to get as far as they could through Halo 2’s cooperative campaign, which is a multiplayer version of the single player campaign. Finally, the control group undertook the social dilemma task first, then played Halo 2 afterwards, representing players uninfluenced by violent gaming.

After playing (or in the case of the control group, before playing), the pairs of players took part in a social dilemma task. The participants were given 4 dimes, and had the option to give any number of dimes to their partner, or to keep them. Any dimes the player gave would be doubled for their partner (i.e. if a player gave 2 dimes, the partner would receive 4). The task had 10 rounds, and after each round, the participants received the dimes the other player gave that round. After analysing the results of this experiment, the researchers found that the players in the cooperative group were more generous than players in the competitive groups, and had increased tit-for-tat strategies, which involve reciprocating opponent’s behaviour, by responding to cooperation with cooperation, and to competition with competition (Ewoldsen, 2012).

Another study was done by Velez et al. (Velez, Mahood, Ewoldsen, Moyer-Guse, 2012) on the effect of cooperative games on player behaviour. In this study, 80 volunteers were split into two groups, cooperative or competitive. In each group, instead of playing with/against another volunteer, the participant played with a confederate staff member posing as a volunteer. The participants then played the team deathmatch mode of *Unreal Tournament 3* (Epic, 2007), a team-based competitive game, with the confederate. In the team deathmatch mode, two teams of players compete for points by killing members of the other team. Participants in the cooperative group were on the same team as the confederate, while participants in the competitive group competed against the confederate. To test in-group/out-group bias, the two groups of players were split again into either in-group or out-group. In the in-group condition, the confederate wore a shirt that matched that of the participants university, indicating that the confederate was in the same “group” as the participant. In the out-group condition, the confederate wore a shirt from a rival university. The shirt of the confederate was brought to the attention of the participant by the staff member running the experiment through scripted dialogue with the confederate.

After playing together, the participant and confederate took part in a social dilemma task like the one in the above study. In this task, however, each round the confederate gave what the participant gave in the previous round. From this study, the researchers found, as above, that participants who played cooperatively were more generous. The donations of the competitive players, however, started low, but steadily rose until the donations of the competitive players matched those of the cooperative players (Velez, J. et al., 2012). The researchers attributed this to the tit-for-tat strategies employed by the confederate, which punished low donations, and rewarded high donations.

This literature review identifies that there is a gap in research about cooperative design pattern combinations. No research has yet been done into how cooperative design patterns could be combined, and the effect that these combinations would have on player experience has not been researched either. Identifying potential ways of combining cooperative design patterns will significantly benefit game designers, as it will enable them to implement these combinations in future games. The effect that these combinations have on player experience is also important, as it will inform games designers as to how they should combine the patterns, and which combinations are most beneficial. To fill the gap this project will investigate three of the identified cooperative design patterns, and examine how combining these patterns affects player experience. The identified patterns selected for this research are limited resources, interaction with the same object, and complementarity, which were selected because they are the three closely-coupled patterns investigated by Beznosyk et al, and were found to have the greatest effect on player experience. Limited resources concerns restricting resources to encourage sharing between players; interaction with the same object provides objects that all players can manipulate; and complementarity incorporates player roles that complement each other.

Combining Cooperative Design Patterns

The methodology used for this research was the Design Science Research Methodology (DSRM) (Peffers, Tuunanen, Rothenberger, Chatterjee, 2007), the implementation of which is shown in Figure 1. The first step in this research project was to identify the research problem, and investigate its significance. This was done through a review of previous research into the area of cooperative design patterns, and cooperative games.

After having conducted a literature review, and identified the lack of research into the effect that combining cooperative design patterns has on player experience, the second step was to define the objective this research aimed to achieve. The objective of this research was to design how to combine a selection of the identified cooperative design patterns, and evaluate the effect that these combinations have on player experience.

With the theory of the objective established, the third step was the design and development portion of the research. For this research, that consisted of designing how to combine the selected design patterns, and developing game artefacts implementing the combinations. Beznosyk et al.(2012b) found that, of the patterns they tested, the closely-coupled patterns had the greatest effect on player experience. Therefore, this project combined the three closely-coupled

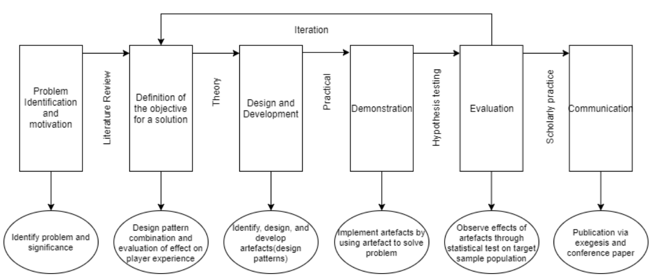

Figure 1. Methodology

patterns researched by Beznosyk et al. (2012b), which are complementarity, interaction with the same object, and limited resources. In order to maintain consistency and simplicity of design, all the developed games utilised object collection as a key mechanic. Once the practical artefacts were developed, ethical clearance was obtained, then participants were asked to play these game artefacts, and provide feedback about their experience, demonstrating the implementation of the combinations.

To create a bench mark to compare the combined patterns against, a single-pattern game was also developed for each of the chosen patterns. This involved iterating through the steps of objective identification, design and development, and implementation again for each pattern. Once the single pattern games were developed, participants were asked to play and provide feedback for each the single-pattern games.

Once the feedback from the single pattern and combination games was obtained, hypothesis testing was used to evaluate the effect that combining the patterns has on player experience, by comparing the feedback from the combined pattern games to the feedback from the single pattern games. Finally, the results of this research are being communicated through scholarly practice, via this thesis.

Combination 1

The first pair of patterns is complementarity and interaction with the same object. Complementarity involves players using different character roles to complement each other's actions. Interaction with the same object gives players objects that both players can manipulate. The prototype implements both interaction with the same object and complementarity through the use of a cart that collected objects are deposited into. Players act as one of two complementary roles, either an object collector or a cart mover, and interact with the cart based on their role. The object collector picks up the objects and deposits them into the cart, while the cart mover grabs the cart, and moves it around to be closer to the objects. A screenshot of the first combination can be seen in Figure 2.

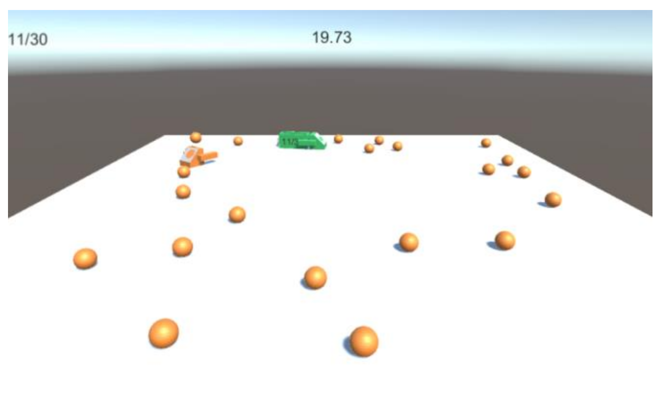

Figure 2. Combination 1

Combination 2

The second combination is complementarity and limited resources. Limited resources relates to having limited resources in the play area, to encourage players to share and exchange the available resources. In this prototype, both players collect objects, however complementarity is implemented by restricting which objects players can collect. Each player can only collect one type of object, and must rely on the other player to collect the other type. For example, player 1 can only collect toy torsos, while player 2 can only collect toy legs. They must work together to build a complete toy. Limited resources is implemented by having a limited number of each object in the play area, and by encouraging players to swap their objects from one type to the other if their partner is struggling. Figure 3 shows a screenshot of the second combination.

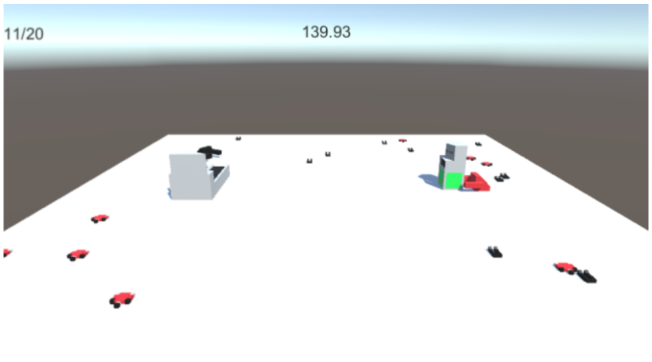

Figure 3. Combination 2

Combination 3

Combination 3 is interaction with the same object and limited resources. Players are provided with multiple objects that they must deposit into the corresponding bin. Players are unrestricted by role, and can interact with any of the objects, implementing interaction with the same object. Players are restricted by area, however, with each player only having access to one object bin. Players must share and swap objects to put each object in the correct bin, implementing limited resources. A screenshot of Combination 3 can be seen in Figure 4.

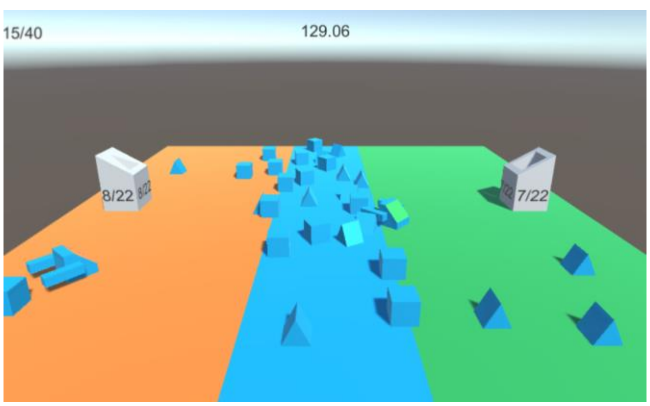

Figure 4. Combination 3

Prototyping, Results, and Evaluation

Implementation

During the implementation of the prototype designs in Unity 3D, a few design considerations were made to improve ease of use and players' experience of the games. When the players first start the games, they are provided with a tutorial level, where they can familiarize themselves with the controls and objectives of the games. The role that each player takes in the games is also randomized. To reduce accidental bias from the researchers, player roles are assigned randomly at the start of a game, so neither the researchers nor participants know what role they will take until the game starts. Finally, player's avatars in game are textured to match the role and abilities of that character. For example, in the second prototype, the character that is able to pick up and move the toy torsos is coloured red, like the toy torso, and has an image of the toy torso on the side of the character that faces the player.

After each game, the participants filled out a survey where they provided feedback about the game they just played. The survey consisted of a series of Visual Analogue Scales (VAS), measuring criteria relating to player experience, like excitement, engagement, level of challenge, understandability, and replayability.

Hypotheses

To evaluate the impact that combining the design patterns has on player experience, the prototypes are being compared based on five criteria: excitement, engagement, level of challenge, understandability, and replayability. Five hypotheses have been formulated, one for each criterion, to determine if combining the design patterns does improve player experience:

H1: Each combination provides greater excitement than each of the individual patterns it consists of;

H2: Each combination provides greater engagement than each of the individual patterns it consists of;

H3: Each combination provides a greater level of challenge than each of the individual patterns it consists of;

H4: Each combination provides a greater level of understandability than each of the individual patterns it consists of;

H5: Each combination provides a greater level of replayability than each of the individual patterns it consists of.

Results

To determine the effect that each combination has on player experience, the hypotheses are checked for each game. This identifies which combinations are the most effective, or have the greatest impact on player experience. All the tests used a significance level of 0.05. The results of each hypotheses for each combination are summarized in Table 1.

The first hypotheses criterion that was evaluated was the level of excitement for each game. For each combination, there was no increase in excitement compared to the single pattern games.

The second criterion is the level of engagement. The first two combinations showed no increase in the level of engagement when compared with the single pattern games. The third combination, Interaction with the same object and Limited resources, however, showed a greater level of engagement than both of the individual patterns it consists of ($p=0.028$ and $p=0.003$, respectively).

The third criterion is how challenging the combinations were. Most of the combinations showed no increase in challenge when compared to the single pattern games, however, the third combination had an increased level of challenge compared to the Limited resources game ($p=0.029$).

The fourth criterion is the level of understandability for each game. None of the combinations showed an improved level

Combination	Hypotheses				
	H1 Excitement	H2 Engagement	H3 Challenge	H4 Understandability	H5 Replayability
Complementarity and Interaction with the same object	No difference	No difference	No difference	No difference	No difference
Complementarity and Limited resources	No difference	No difference	No difference	No difference	No difference
Interaction with the same object and Limited resources	No difference	Improvement over both patterns	Improvement over Limited resources	No difference	Improvement over Limited resources

Table 1. Results of hypotheses

of understandability when compared to the single pattern games.

The final hypotheses criterion is the replayability of the combinations. Most of the combinations showed no improvement in replayabiliy, except for the third combination. The third combination, Interaction with the same object and Limited resources, had an increased level of replayability compared to the Limited resources game (p=0.003).

Evaluation

Overall, combining the cooperative design patterns had no effect on player experience, with the exception of combination 3, Interaction with the same object and Limited resources. Combination 3 was found to be more engaging than both the individual patterns in consists of, and more challenging and replayable than the Limited resources game.

The lack of difference between the combined and single pattern games for the excitement and understandability metrics is possibly due to the simplicity of the developed games. All the games are uncomplicated, and use similar mechanics, so the difference in understandability would be low, and there wouldn't be a significant increase in excitement either.

The increased level of engagement for combination 3 is most likely due to the interactive nature of the in-game activities. Compared to the other two combination games, game 3 consisted of more swapping items with, and interacting with the other player, and this constant collaboration may have caused players to be more engaged with their partner, and the game.

While the games are simple and uncomplicated, the game for combination 3 is the most complex of the games, and the limited resources game is the least complex of the single pattern games. This is likely why combination 3 was found to be more challenging than the limited resources game.

Finally, the increased level of replayability for combination 3 compared to the limited resources game is likely due to the increased complexity and engagement of combination 3.

Conclusion

This research investigated cooperative design patterns to determine if combining them improves player experience compared to individual patterns. Previous research identified the effect that several cooperative design patterns have on player experience individually, and suggested the need to investigate the effect that combining them would have. This research attempted to extend that, and examine how combining cooperative design patterns affects player experience.

This research found that, overall, combining cooperative design patterns has no effect on player experience. The third combination, Interaction with the same object and Limited resources, was found to be more engaging than the individual patterns it was comprised of, due to the interaction, complexity, and nature of the game. With the exception of the level of engagement for combination 3, however, there is not enough evidence to support that combining the selected cooperative design patterns improves player experience. This prompts further research into the effect that combining other cooperative design patterns has on player experience, and if increasing the complexity of the combinations has an increased effect on player experience. This research also prompts investigation into other ways of implementing cooperative design patterns to improve player experience and collaboration.

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A Generic Architecture for an Ecosystem of Autonomous Artificial Animals using Dynamic Considerations

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Abstract

Using Artificial Intelligence and Non-Player Characters in games has begun to increase rapidly. This is due to both player expectations and availability of new hardware and software technology (Dragert et al, 2012). Artificial Intelligence can increase a player's immersion and experience with a game as the player see realistic and dynamically reacts to occurrences. However, there is a lack of generic design and implementation of Artificial Intelligence systems that employ more complex algorithms that can be easily integrated and scaled. A common example of a scenario that needs a generic Artificial Intelligence system is an ecosystem of autonomous artificial animals. This research aims to design and implement this system for a simulated virtual forest environment that resembles forest wildlife. This system will employ the Utility AI theory and dynamic considerations to create an ecosystem of autonomous artificial animals. The generic structure makes us enable to scale up our system easily by adding more species in the forest with minimum changes. This design for this system will be shown as well as a walkthrough of the implementation of the system in Unity3D.

Keywords

Artificial Intelligence, AI, Utility AI, Game, Virtual Ecosystem

Introduction

Recently, the demand for more autonomous AI and Non-Player Characters (NPC's) that have ability to react 'Humanly' or realistically to ongoing events, actions and sounds made by the player has been growing exponentially (Safadi et al, 2017). This is because of growing hardware and software technology that make what was once impossible, the norm. Now AI and NPC's can increase immersion and consequently improve experiences for the player. This is formulated through observations made based on how they act, how they are dressed, what they say etc. Each component of the AI must be carefully designed to fit into the overall system. If this is done correctly and the design of the AI fits with the games design, it has more chance to increase player satisfaction.

Autonomous AI can improve player satisfaction with a game by simulating a living world around the player. They employ powerful dynamic techniques to observe and react to its environment. Matt Buckland (2004) defines an autonomous AI as one "that is situated within an environment that senses that environment and acts upon it, over time, in pursuit of its own agenda, and to effect what it senses in the future.". Autonomous AI therefore act based on its own desires, trying to fulfil these desires (to stay alive, drink, eat etc.).

There is a wide selection of AI techniques that can be used to simulate autonomous behavior, these include Finite State Machines, Behavior trees, Utility AI, Goal Action Oriented Programming (GOAP) etc. Among these techniques Utility AI (UAI) is one that offers the most promising to react realistically to ongoing events especially when dealing with an edge case scenario. An edge case scenario is a situation that causes an AI system to not operate as planned, this could be getting stuck on parts of the game environment. UAI systems handle edge cases gracefully [Get Ref] because there are no explicit transitions between actions. An ecosystem of autonomous artificial animals includes several kinds of animals that will perform actions and tasks based on their needs and wants, some will be predators, others may be prey. This project proposes to design a generic architecture using Utility AI (UAI) to create an autonomous ecosystem that resembles and mimic a forest wildlife.

Related Work

Each AI technique can be useful for different scenarios, some are far more complex than other, but as stated by Millington et al (2009) these techniques just must be used correctly to achieve the desired output. Some of these techniques such as Genetic Algorithms, Neural Networks, Utility AI (UAI), Goal Oriented Action plan and even Neural Evolution have not been widely adopted into the gaming industry (Champanda, 2017). There are a few reasons for this mainly because these systems are not scalable in larger environments and some of them are taxing for performance. Also, AI programmers have little processing power to work with after all the other elements of the game are added. This accompanied with the pressure for them to output complex realistic AI within a short period of time leaves them falling back to tried and tested techniques that they can easily implement (Fairclough et al, 2001).

Individual AI entities within the game environment can be split up into three main roles: movement, decision making and strategy as stated by Millington et al (2009). Movement refers to the algorithms that help the characters to find an optimum path to move and avoid obstacles within a game environment. Strategy refers to how the AI behave with one another. Its task is to allow the AI to share information between one another, usually by the black board method (Miyake, 2016). Decision making is the core of the AI, it acts as a brain for the AI, taking information from the game world and assigning tasks to the AI. One of the efficient algorithm for decision making is UAI and has the potential for a generic implementation and scalability.

Utility AI is based on the Utility Theory which has been used in other fields like economics. Utility AI is used to mathematically model an AI as it isn't possible for an AI system to know what is preferable over something else as stated by Mark, D & Dill, Kevin (2010). Each evaluated action receives a normalized value between 0 and 1, which can be considered as how much the AI desires the action. Each action to be executed also needs another value called score for considerations. The consideration relates to the actual AI's stats such as health and energy. The normalized value of the stat is passed into a curve that returns the score for the consideration. For example, if there is an attack action, the considerations for the action would be if the AI entity has enough health / energy to execute the action. UAI systems can be used for other applications other than choosing actions. For example, the game Killzone used a dynamic UAI system so their AI can choose the best possible cover in a fire fight Straatman et al (n.d.). Other applications include choosing a deck of cards in the Hearthstone game (Stiegler et al, 2016). Just from this we can see the wide range of possibilities and functions these systems offer.

Sloan et al (2011) explain why Utility AI technique hasn't been widely adopted by the gaming industry. Mainly due to lack of control over the systems and being difficult to craft complex behaviors, the system being resource intensive and because it is difficult to scale in large environments. However, they disprove these former two arguments by showing how Utility AI compares to other techniques like Goal Action Oriented Programming and Finite State Machines. The Utility system used more resources than the Finite State Machine, however less that Goal Action Oriented Programming and they could construct complex behaviors with the system. They still found it doesn't scale well in large environments, but by creating a generic architecture, scaling the number of species will be easier to accomplish.

Unlike FSM's, Utility AI don't require transitions (Aitchison, 2017). All the actions are decided at run time based on dynamic variables. There is nothing set saying in this situation do this, rather telling the AI what the most desirable in the current situation. This is a major benefit over FSM's because when using FSM's, as the complexity of the AI grows, so will the size of the code base exponentially. Because we don't need transitions, all the logic can be self-contained within the actions classes. However, this gives the AI a vast amount of the power making it harder to debug, but helping the AI to handle events more dynamically and gracefully as stated by Mark, D & Dill, Kevin (2010).

This literature review identifies a lack of a generic design and implementation of Utility AI systems in games. A common scenario where Utility AI can play a very important role in games is an ecosystem of autonomous artificial animals. Therefore, this research aims to implement a generic ecosystem using a Utility AI system which works within a simulated virtual forest environment.

Ecosystem of Autonomous Artificial Animals

This section will contain the design techniques for creating the Utility AI system. The goal for this system is a modular design that will be easy to implement and extend upon. This follows a component based design. Component based design attempt to simplify a major system into sever sub systems or components (Lampka et al, 2012). Each part has its own functionality and it does one part of a much bigger system. This design will help with an iterative process because it allows the programmer to work on the components individually and it has increased readability and allows for easier debugging.

Figure 1 shows the UML class design for the action components. The starting point for the design of this architecture is using Interfaces. Every script in the core Utility AI system will implement an interface. The main reason for using interfaces in this case is scalability. In the future if we need to add more functionality all we need to do is add another method to the interfaces. Also, the interfaces help referencing the generic components. This way when we have a list of actions we don't need a list for each generic type we can reference it through the interface.

Next in the hierarchy is a basic action abstract base class. This class holds the information that will be shared between every basic action and normal action. The basic actions are ones that can run at any time no matter the circumstance and don't require considerations, for example, searching for items or inspecting an object. The basic actions are a relatively simple script, mainly contain variables for the action name, start and finish time, variables for enabling and interrupting them etc.

For the case of the actions it is more appropriate to have an abstract base class, however, not every component will need this abstract base class. The base classes will receive the function calls from the interfaces and call the corresponding abstract functions. This means that each class can have a Start Action method with the different functionality in them as well as a Start Action in the base class where we can handle the logic that is shared between each of them. The actions base class will also handle starting, running and exiting internally.

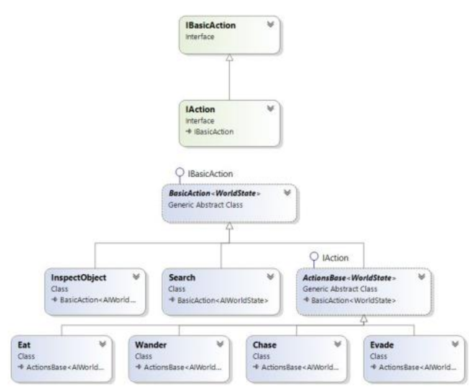


Figure 1: Actions UML

Each action will need to have a method that calculates the desirability of the action. This method will loop through the considerations that are relevant to the action and score them. How these are scored will be covered later in the paper, but this evaluation function will update the action utilities for the action selection process. Each base class has a generic type, the generic type must be a class that implements the world state interface. The world state is a class that holds variables that are unique to the specific AI. It also holds references to different components of the AI such as the considerations and the AI mind. This is so that we can check and alter values. So, this class allows the actions to get a reference to the AI's world state that owns it. This will be helpful when we want to change values for their thirst or hunger once they complete the action.

Figure 2: Core Utility System

Figure 2 shows the UML for the Utility Action Selector, which is separated into three main parts; the Utility struct, the Utility AI Agent and the Decision Maker scripts. We need a way to give each action some utility, this utility, as mentioned before can be thought of as a single float value from 0 to 1. But we also want to be able to weigh these utilities so we can adjust these weights at runtime based on other variables. This is useful for situations where a bunny, for example, might be wanting to drink but there is a fox chasing after him. We don't want to consider the drinking action until after we are safe, so we drop the weights of these to 0.

The Decision maker triggers the action selection process by calling methods in the utility AI and ensures that there are active actions before executing the actions. The decision maker also handles the running, pausing and interrupting / switching of the basic actions. Once the action selection process has been triggered, the Utility AI loops through all available actions and chooses the highest scoring option. Note that there are several ways one could choose an action based on the utility values returned from the evaluation. Some include the aforementioned max utility, weighted random and sequential selectors. For this project we will only be using the highest utility so the UAI agent loops through the utilities to find the highest scoring action to return.

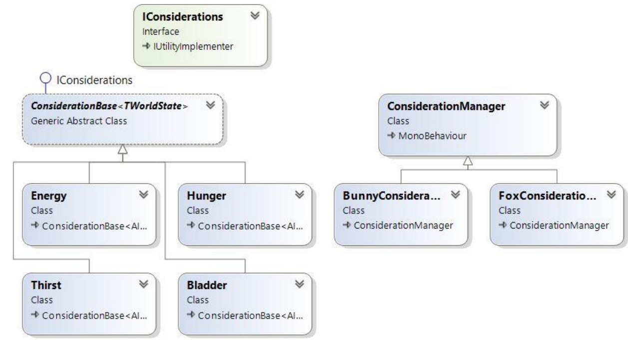


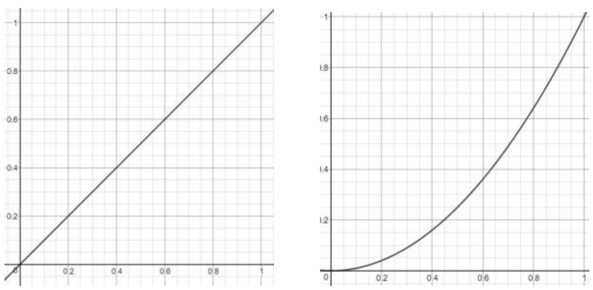
Figure 3: Considerations UML

Figure 3 shows the design for the Considerations; each AI has a considerations manager. The main concept for the considerations is to give context to deciding what actions to take, these can be the AI's health, thirst, hunger how many enemies are around etc. This consideration manager will hold references to the considerations that are constant and those that are made dynamically and update them. For example, health is a constant consideration, it will change but there will only ever need to be one per AI. However, a consideration for judging distance from objects or other AI entities will need to be dynamic so we can assess more than one object / AI at a time. This way if an AI wants to eat and there are several food sources in the area it will just each food source based on type and distance. This also means a fox that sees a group of bunnies' it will chase the closest one. These would get updated at a certain rate so that if another bunny gets closer, it can switch chase targets.

Each consideration will need to be updated and evaluated and these will be different for most of the considerations. So, it is appropriate to follow the actions design with a generic abstract base class. This way we can create the AI type specific considerations if we want to change how one considerations is updated or evaluated based on the AI type. The considerations will need to also hold a utility that get updated on evaluation. This will allow us to weight the considerations so that the ones that are more important such as health can be considered first.

The way the considerations are evaluated is through response curves, these curves allow us to essentially model the AI's behavior (Mark, D & Dill, Kevin (2010)). Consider a scenario where a bunny sees a fox, if the fox begins walking towards the bunny, the bunny should gradually begin to get afraid. Eventually the fox will get close enough that the bunny wants to run away. Without a curve the behavior would act as though the bunny is normal until the fox gets to the evading distance and instantly becomes afraid. This could be a Boolean operation, it gets to the trigger point and switches, this functionality is not desirable for realistic behavior. Each curve will be using normalized values and outputting normalized values between 0 to 1.

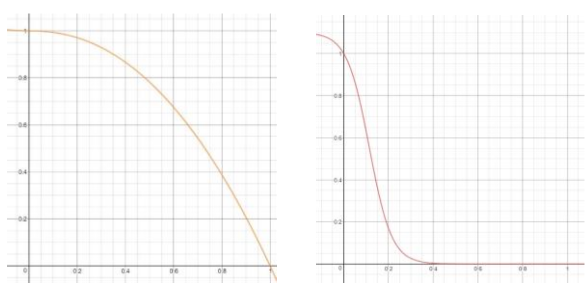
There are plenty types of curves that can be used to model an AI's behavior, each curve can have a purpose for different circumstances. With the wide range of things, we can do to manipulate and alter the curves, we can get very diverse behaviors emerging from the AI. It is important to note that the x axis for the curves are arbitrary, this could be distance, amount of health, number of enemies etc. and the y axis is the output or the utility of the certain thing. Both the x and y values are normalized between 0 and 1 for simplicity and evaluation of actions.



(a) **(b)**

Figure 4: Straight Line and Quadratic curve

Figure 4-a shows a straight line carve that is useful for calculating the utility of an AI such as energy consideration. The higher the energy, the less likely an AI wants to do actions like sleep but higher probability to do action such as chasing another AI such as bunny. Figure 4-b shows a quadratic curve parabolic curve which has a slow build up at the beginning but begins to rise faster the higher the x value. This is useful for situations where we want to evaluate considerations like hunger. The closer we are to the max hunger, the steeper the curve should be because we never want to reach full hunger otherwise the AI will die.



(a) (b)

Figure 5: Exponential Curve and Logistic curve

Figure 5-a shows an exponential curve that can be used to measure different things such as breeding rates over time. Another use could be modelling the behavior of a very scared AI such as bunny. It means if a fox comes close to the bunny it will be more likely to run away at a longer distance if spotted.

Figure 5-b shows a logistic carve which grows at a fast rate, however at a certain point they will cap out and begin to grow at a very slow rate. This could be used to model how the AI reacts to distance, for example, if an AI wants to eat a food item, generally it will want to go for the closest item (unless it prefers another food object). This means that for distances of 0, the AI will 100 percent want that item based off distance. This means if the AI is searching for water but hungry at the same time, we can evaluate the closer objects and evaluate our stats and if applicable change to the eating action.

Now we have the core system design in place we will need some way for the AI to move around the environment. There are a few ways to handle AI movement, some include the A* search algorithm, the dijkstra's algorithm and the steering behaviors described by Matt Buckland (2004). Each technique has different uses, the A* and dijkstra's algorithm work similarly to each other by finding the shortest path in a grid of points. The main problem with these methods is that they require grids that cover the entire environment. This can be segmented but at the same time if we want to update the grid we would have to go through and update the entire grid. This means that there could be spikes in frame loss when it does update if the grid is too big. These methods would work well for a static scene, meaning no objects get moved around the scene.

The steering behaviors described by Matt Buckland (2004) offer a dynamic movement system that requires no grids. It is described in his book as Autonomous movement, meaning the AI is deciding on the movement direction based on what behaviors are being analyzed. These behaviors include Seek, Flee, Evade, Chase, Interpose, Arrive, Wander and Collision Detection. Each behavior can be separated into component scripts and will return a single movement vector with the desired direction and speed to be used by the main movement script. It will convert the force into an acceleration to apply over time.

Each desired movement vector received from the steering behaviors will be added together with weights to get the overall desired movement velocity. We weigh these vectors so that we can prioritize and get a different overall behavior from the AI. For example, the Collision Detection behavior should have a very high weight, because above all else we want to avoid hitting rocks and trees. However, the Wander will have a very low weight to it because that is something we only want to consider if there is nothing else to do. Finding good combinations of these behaviors can offer great results, for example if a bunny is evading a fox, we have Evade enabled as well as Wander enabled so that there is some slight randomness to his movements and not running away in a straight line.

Prototyping, Implementation and Evaluation

The chosen engine to implement this system for proof of concepts is Unity3D. The modular design for this will make it easy to implement and add actions, considerations and AI types. Because we do not need to program explicit transitions between the actions, we won't have to program as much. The implementation method used for this is an iterative process, we first get the core system in with one animal and two actions then build upon it. The first animal to be implemented will be the bunny and will have an eat action that has the hunger and energy and a drink action that has thirst and bladder. As the value for hunger rises and the value for energy decreases, the overall action score will increase.

Before covering the bunny and the two actions, we first must define something to use as a utility value so actions and considerations can be used. This is done through a struct. A struct is a value type that can hold small groups of related variables. This is perfect for the current situation, we need to a float value between 0 and 1 for the output but we want to be able to weigh it. So, we can use structs to hold two float variables for the value and weight and have methods for getting the combined. This means we can create them dynamically.

Once we have this we can create the world state classes so that actions know which AI to affect. This will contain references to several scripts including movement, the agent mind and the vision. Most actions will need to affect variables in these scripts. For example, when finishing the eating action, we want to remove some hunger from the AI and add some energy this is done through the reference to the considerations manager in the world state class.

For this project we will only have the one world state, because we won't have any major changes in the functionality. The design of the world state is so that each AI would have their own specific world state class, this means we could have one for the animals and if we needed to add in Non – Player Characters, have one for them to differentiate the functionality between the two. Now we have some way to gauge the AI's desire towards a specific thing we can start creating the actions and considerations. The first thing to do is decide on the functionality required of them so we can implement the interfaces. This can be constantly updated at any point, but all deriving classes must have an implemented version of the methods in the interface.

To begin with the considerations base and the AI consideration managers will be implemented, we need this first for the actions so we can evaluate and choose the appropriate action. The main functionality needed by the considerations is the evaluation and updating. As mentioned before we will be evaluating the consideration based on curves. We can do this mathematically with the aforementioned formulas. However, unity offers an inbuilt curve editor for animations which will work perfectly for the current situation. This curve editor allows us to get a better visual indication of how the AI is behaving.

Because each consideration will need to be evaluated and updated individually, the interface functions must call abstract methods in the base class. The abstract Consider method must be implemented by all deriving classes, the unique code will be placed in those methods this means we only have to call the one function from the interface which will execute the unique code for each consideration.

Once we have all the functions connected in the base class we can begin implementing the specific consideration. To begin with this will just be Hunger, Thirst, Energy and Bladder. This way we can get the core system in place moving between eating and drinking action before expanding. Before we begin implementing the evaluation and updating, we need some value to represent the consideration. This will be a value between 0 – 100 for general purposes. Within the Consider function, this is normalized using the $\frac{x}{m}$ formula.

As mentioned previously some of the considerations may need to be flipped, for example when a fox evaluated chasing a bunny, the energy consideration will need to be flipped because we want a higher value the higher the energy consideration is. Because we normalize the inputs before evaluating, if we need to reverse the curve all we need to do is use the formula $1 - \frac{x}{m}$. In order to update the considerations over time, each AI will need a considerations manager, this will handle adding the considerations at runtime and updating their values based on the game state / AI's world state. For example, if the AI is moving around, we should be getting an amount to take off the energy consideration every n seconds. We set a maximum value that can be taken away at any one time and get the normalized speed of the AI to generate a number. So, $Energy = ML * \frac{s}{MS}$; where ML is the max loss, s is the current speed and MS is the max speed. This means that the AI must be going full speed in order to lose the maximum amount of energy.

The actions interface inherits from the basic action so it has all the functionality of the basic actions plus the additions. There will be a basic actions base and a normal actions base. The basic actions will not contain much functionality, all that needs to be done is executing the main loop. Each action will contain specific functions for their needs, for example the inspect object basic action will have a function to set the inspecting object.

The actions however will need to be more complicated, some may need to be interrupted, an example of this is when a bunny is in the eating action and spots a fox chasing him. We want to pause the eat action and begin running away. This means in the decision maker we can also keep track of the previous action if we interrupt one to continue after.

One basic action will be created for the first iteration, this is the search basic action. The eat and drink actions will require the AI to find the appropriate items for the action, this is done through the search basic action. When we begin the eat or drink action, the tag/s to search for will be set and the search basic action will enable the wandering steering behavior and signal the vision script to keep a look out for the tags each time it updates.

The results are stored in a list that the actions can access, these actions then choose the best item based on distance, for the eating actions it will also rank it based on the food type. We can also add other conditions to it such as checking for enemies near-by.

Now we must implement the evaluation of actions. The way we do this is by scoring the considerations associated with this action. So, we will need to add these considerations at start. This is done through the abstract method Add Considerations, we want this abstract so the deriving classes can set the unique considerations for each action.

Once we have this we can begin evaluation. There are different ways that we can add these consideration values together, initially the most appropriate might be to get the average of the consideration values. So, we would have $value = \frac{c_0 + c_1 + \cdots c_{max}}{c_{count}}$. But in some cases, if a consideration returns 0 we won't want to consider that action at all. For example, a fox considering chasing a bunny will want to chase only if it has enough energy, can see a bunny and is an acceptable distance away. If the fox has only 5 energy left we don't want to waste it chasing the bunny otherwise it will collapse and die.

A method of combining these was devised by Mark, D. (2013) called the infinite axis system. Infinite axis relating to the modularity in the design that allows for infinite consideration to be added to actions. The premise behind this is that when we have a group of consideration to be evaluated, we multiply them all together. So, the formula becomes $value = c_0 * c_1 * \dots c_{max}$. This means that in order for the action to have full utility every consideration must return the full value of 1, however if any return 0, the actions score will be 0.

All the actions handle their own starting, running and exiting all controlled in the execute action in the base class. First, we want to check if the action is running and we are able to run the loop, if not we want to start the action. It is important to note that at this point, there will definably be an action to execute, in the previous methods we have done checks to ensure this. This way we can have all the functionality contained all within the one script.

(a) (b)

Figure 6: Fox Object Detector and Bunny Object Detector

Within the main loop we want the specific action logic, for the most part it just chooses the object it wants to get and waits until the AI reaches the object. At this point it plays the correct animation for the action. The way we can tell if the AI has reached an object is by using a small trigger collider that is attached to the jaw bone of the model which can be seen in figure 6-a and 6-b. This is for accuracy and simplicity, another way to do it would be a distance and angle check, however this way when a fox is chasing a bunny, we can use the collider to accurately tell if the fox has bitten the bunny.

Now that we have our actions and can evaluate them we can hook them up to the decision maker and utility AI. The decision maker, as previously states triggers the decision-making process, like the actions, it contains a enum for the current state. This is so we don't trigger this process when the AI is not active. The decision maker loop is run by the agent mind script a. Because we want this system to be dynamic, the decision maker is constantly checking for actions that has better utility than the current one. However, in scnearios where a bunny is being chased but it managed to get far away from the fox, the utility for evading will drop, however we don't want to consider any other action untill we have stopped being chased.

The action selection method ensures enough time has passed since the last action check before beginning to chcek for a new one. Within the AI Got Action method, it calls a method in the utility AI that updates the utilities of the actions and chooses one. This way the Utility AI handles the selection of the actions based on their score and the decision maker runs the actions code.

The agent mind is a key part of the AI, it initializes and updates all the components in the AI. It also keeps track of items that the AI has encountered, for example a body of water, these areas will need to be remembered so that we can easily go back to them next time we want to drink. We can also hold areas where there is food for example a berry bush or an area bunny's are occupying. We can access this when we begin actions to skip the searching and increase the interval in vision checks to save resources.

The known locations of items are stored within a dictionary, using the tag as the key and the location as the value. The agent mind script contains functions for finding areas within the dictionary as well as saving, so the actions can access this through the AI world state.

Each AI type will have a deriving class from the agent mind script. Within these scripts, the list of objects that has been tagged is sorted. In here the environmental obstacles are sent to the movement script, other AI types are tagged to a list which can be used by the distance considerations for the chase and evade actions.

The way we tag objects is using trigger colliders in unity, we can make a fairly large collider that has a simple script tagging the items to the list in the agent mind. There are other methods unity has that can accomplish the same task such as using a physics overlap sphere, however these methods are often taxing on the performance.

The AI's vision holds a list of tags for objects to look out for whenever it performs a vision check. This is done at a set rate for performance reasons. The vision check will be done in three steps; an initial distance check is performed to ensure we don't have any objects that are far away, next an angle check is performed to make sure it is in front of us and finally a ray cast is sent out to the object to ensure no objects block the line of sight. This three-step process means that every AI will not send out a ray cast to all the tagged objects so it will not consider the items behind. This will boost performance especially if we want to have lots of AI's roaming around.

The hearing component of the AI keeps track of sounds being played as well as dynamically creating consideration for these sounds. If the AI can hear another AI moving, it will set the consideration for the look around basic action which makes the AI face the sound direction. We create these dynamically for each sound so that in the look around action we can score these based on the volume or distance away. This will choose the most appropriate sound position to look at. Like the vision, this is updated a regular interval.

Now we have the components required for two AI types, two actions and their associated consideration we can piece it together to get it running. From this base it will be easy to extend. The rest of the actions can be easily implemented and tweaked as well as the considerations due to their minimalist structure. As we extend on this system it will start to run slower. So, some optimization techniques will need to be implemented into the system to ensure the game runs at an appropriate frame rate.

(a) (b)

Figure 7: Fox and Bunny Implemented

Figure 7-a and 7-b shows the bunny and the fox Implemented into Unity3D. Text is showing all the considerations that they consider for making decisions and their current action. As the simulation runs, certain considerations get altered (Energy, Hunger, Thirst etc.). These can be updated based on the game world state. For example when updating the Energy consideration, we can take into account the time of day / heat and how often the AI is moving to detract a value from energy.

Some of these techniques have been stated previously; when considering how an AI conducts action selection and updating the different components, we should consider how long these should take. For example, we don't want to be checking for an action every frame. Once we have an action there should be an interval the AI has to wait to check again. This principle carries over most components, by appropriately timing the updating of components we can ensure the correct components get updated first as well as optimizing these components.

Using trigger colliders have also helped performance, instead of using the physics sphere checks to get a list of tagged items we can tag them when they enter the trigger and when they exit. This way we don't check every item each check, we tag them once and un tag them when appropriate.

Doing this allows us to really break down the AI into even smaller bits to make sure every section is working as intended. We want to make sure that the animals go into the right actions at the right time to get the right behavior.

Figure 8: Fox Chasing Bunny

Figure 8 shows the system after being extended more. Another action was added to the fox and bunny for chasing and evading respectively. For these actions more, considerations were added such as threat and distance from target. From the already developed system, adding these actions was easy.

Conclusion

By increasing the power and decreasing the cost of new hardware and software technology the demand for increasing immersion and improving user experiences have been growing exponentially. This demand can be easily addressed using autonomous AI and NPC's that have ability to increase immersion and consequently improve experiences for the player.

There is a wide selection of AI techniques that can be used for these purposes. Among these techniques Utility AI (UAI) is one of them that offers promising results to react realistically to ongoing events which is a main factor for player immersion. A common example of a scenario that AI and NPC's can play a very important role is an ecosystem of autonomous artificial animals. As we have been describing, this research designed and developed a generic architecture using Utility AI (UAI) to create an autonomous ecosystem that resembles and mimic a forest wildlife. This generic structure makes us enable to scale up our system easily by adding more species in the forest with minimum changes.

There are a few ways that this system could be improved, (1) the action selection process could be run on another thread; (2) implement a faction based system to make the designed system more realistic; (3) improve the design for the considerations by separating their functionality; (4) increasing the complexity of AI and actions that works together as goal oriented actions.

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Repurposing Augmented Reality Browsers for Acts of Creative Subversion

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Abstract

Consumer facing Augmented Reality (AR) technology offers innovative new ways for consumers to engage and interact with brands and products via interactive advertising and experiences. Conversely, this technology also creates new channels that can be exploited and subverted by those who wish to generate critical reflection of consumerist culture. This paper aims to highlight that consumer AR technology presents new and unique opportunities for activists interested in subversive communication.

Keywords

Augmented Reality, Creative Disruption, Activism

Introduction

While designers working with political and/or activist intent is by no means a new concept, in the graphic design space there has been an increasing amount of interest and discussion around where the focus and energy of practitioners should be aimed. Broadly, it has been said that the current industry has devolved to predominantly serve and maintain an "environment so saturated with commercial messages that it is changing the very way citizen-consumers speak, think, feel, respond and interact" [1]. It has been suggested that those who can should be using their abilities as cultural intermediaries to rather be challenging and exposing the inadequacies of the status quo for the greater good of our society [2–4].

One act which aims to challenge and subvert communications of the mainstream media, 'culture jamming', has been brought to prominence over the last twenty years by the Adbusters Media Foundation through their anti-capitalist magazine *Adbusters* and other publications [5]. Culture jamming uses the practice of 'détournement' propagated by the avant-garde Situationist International collaboration in the 1950s and 1960s to generate "simple acts of creative resistance that raise awareness, reframe debates, and reclaim and maintain individuals' sovereignty" [6]. The Situationist International were concerned that we live within a modernist representation of reality delivered through mass media known as the 'spectacle'. The act of détournement was conceived to reveal the spectacle of everyday life through the creation of "expressions that de-familiarize the spectators so that they must take on a distanced critical reflection upon the spectacle's underlying processes of exploitation" [7]. In the case of culture jamming, détournement has been deployed by activists through a wide variety of activities—from inserting colourful knitted objects into the urban landscape [8], to coordinated events where advertising in the public sphere is simultaneously removed and replaced with alternative messages [9].

Augmented Reality (AR) refers to "a real-world setting or set of objects" being "augmented by a computer-generated overlay" [10]. In the broader marketing, advertising and media landscape, consumer facing AR (through the use of a smart phones, tablets, or wearable devices) has been promoted as another channel to engage consumers within a heavily saturated digital environment [11]. The typical use of AR in this manner has been to create 'hypermedia' opportunities, where digital information and media is superimposed over traditional print based objects such as advertising, packaging, and signage [12].

This paper aims to highlight that the ability to augment information over reality offers unique opportunities to those interested in revealing the otherwise obscured spectacle. Consumer facing AR in particular should be further investigated as a tactical tool for creative subversion due to its low-cost accessibility and the low level of technical ability required to create augmentations.

Background

Culture Jamming

While the term culture jamming has been recently popularised by organisations like the Adbusters Media Foundation, it should be noted that the techniques of détournement and creative acts rallying against globalisation, consumerism, environmental destruction, and patriarchal dominance had been proceeding under the banner of culture jamming before it's mainstream popularity.

Dery defines culture jammers as those whom "introduce noise into the signal as it passes from transmitter to receiver, encouraging idiosyncratic, unintended interpretations" [13]. One playful example of disruption mentioned earlier is the practice of 'Yarnbombing', which involves "stealthily attaching handmade fibre items to street fixtures or parts of the urban landscape" [8]. Culture jams can also take the form of advertising 'take-overs' — also known as 'billboard banditry' [13], and more recently, 'subvertising' [14] — where existing advertising is altered to communicate an alternative message. This form of culture jamming can be undertaken by a single activist spontaneously pasting over a sole piece of advertising—or by larger, connected groups with specific targets and objectives utilising high visibility 'camouflage' uniforms and specific keys to unlock panels and access ladders.

As mentioned, the approach of subverting public advertising space has a rich history of activities reaching back far before the term culture jamming was popularised. Notable collaborators B.U.G.A. U.P. (Billboard Utilising Graffitists Against Unhealthy Promotions) targeted cigarette advertising billboards in Sydney, Australia, from 1979 until this form of advertising was banned in 1996 [15]. At the same time in the United States, collectives such as the Guerrilla Girls and the Billboard Liberation Front were also rallying against the status quo using billboard takeovers as their means of dissemination [16,17].

Physical Take-Over Approaches

A recent example of part a large, international, coordinated advertising take-over action can be found in the 2017 *Subvert the City* campaign, which managed to disrupt five hundred advertising panels across multiple continents during a week-long event. *Subvert the City* was co-ordinated and executed by numerous individuals and collectives across the globe under the umbrella of Subvertisers International and their manifesto, calling on activists to take back the public sphere and "imagine an alternative" where "public art and ideas replace advertising" [18]. The campaign included a variety of physical take-over approaches from crude acts of simply defacing billboards with paint to coordinated replacement of bus shelter advertising with pre-printed posters [19].

Included in the Subvertisers International are the group Brandilism, who have notably distributed a professionally designed and detailed *Street Ad Takeover Manual* via their website. The manual includes details on generating artwork, standard advertising print sizes, legal issues, how to create fake high visibility uniforms, and links to other activists who distribute specialised access keys [20].

The *Subvert The City* campaign was also referred to and publicised through the hashtag #SubvertTheCity. Social media has become a significant tool in enabling large scale co-ordination and publicity for culture jamming activities, especially due to the increased availability of internet access via mobile phones [21]. Lasn once proclaimed the internet as being "the most potent meme-replicating mediums ever invented", [5] but even he could not have predicted how effective social media has been at disseminating culture jamming outcomes. The recording and online publication of results creates the opportunity of the jam 'going viral'—being extensively shared online—reaching a far wider audience than those who saw the original physical intervention [6,9].

Using Projected Imagery

Other activists have recognised the potential for reaching a wider audience through documentation and social media. In the case of *Emoluments Welcome* by artist Robin Bell, a 'physical' outcome was only active for a fleeting few minutes in a single location while the published video recording spread much further. In this example, Bell used a concealed projector to project anti-Trump messages such as 'PAY TRUMP BRIBES HERE', onto the façade of the Trump International Hotel in Washington DC. The projector was physically blocked within minutes by hotel security, however images and video had already been shared by the artist and onlookers before this occurred [22]. The projection enjoyed further exposure and media coverage through mainstream outlets including the BBC, CNN, New York Times, and the L.A. Times [23].

A similar intervention was staged in Brisbane, Australia, during the 2014 G20 Summit. In this instance, the artist/designer collective Dirty Work installed disguised projectors into the G20 safe zone, allowing them to project anti-G20 messages such as 'G20: CORPORATE PLUNDER' and 'G20: FESTIVAL OF FAKERY FOR PHONEY FUCKERS' on walls throughout the precinct [24]. Again, like the Brandalism example, detailed and professionally presented instructions for how to create the mobile phone activated projectors they used were later released online [25].

Using projected imagery is an interesting development in that it allows for take-overs with much larger physical canvases as both examples projecting images on buildings far bigger than billboards. Anywhere there is a suitable surface to project onto can become a potential site of intervention, unlike physical take-overs which are limited to existing advertising spaces.

Using Augmented Reality

AR offers unique opportunities for culture jammers to "place their messages at specific locations anyplace on the face of the earth and share those messages with others either physically at the site or online” [26].

While technology enabling AR has existed for some time, there has been an increasing level of hype over the last decade predicting AR to be the next ‘big thing’ in mainstream consumer technology. This hype has intensified in recent years due to the advancements in mobile device technology and mainstream success of apps such as *Pokemon Go* and Snapchat Lenses. Technology giants Google and Apple [27] share this belief and have invested heavily into consumer-facing AR hardware such as the wearable technology like Google Glass, and software like Apple’s ARKit.

In his excellent review of AR activism, Skwarek [26] outlines the few initial ventures that have taken place using this technology and the benefits of using AR as an activist tool. The advantage of AR being able to infiltrate inaccessible locations and spaces is a common characteristic of his analysis.

Skwarek’s own *protestAR* project is a prime example of this. Aligned with the 2011 *Occupy* movement, *protestAR* comprised of inserting a virtual demonstration in front of the New York Stock Exchange. During this time, this location was under restricted access with no ability for protesters to be physically in that space. Skwarek called for protesters to submit photos of themselves complete with *Occupy* placards, which he enabled to be viewed via the app using geo-location.

Another project of note is the augmentation of the British Petroleum (BP) logo in 2010, in response to the *Deepwater Horizon* oil spill in the Gulf of Mexico. Using an marker image recognition technique, this augmentation displayed a pipe spewing oil over the top of any BP. The use of an image that can be found all over the world demonstrated incredible potential for massive distribution of the intervention, as it could be replicated wherever the BP logo was found. As Skwarek notes, when using an image that is meticulously reproduced—such as a multinational organisations logo—the “majority of the work has already been done by the activist’s target” [26].

Similar to the projected outcomes outlined above, AR allows for interplay and interaction between ‘reality’ and overlaid imagery, offering an opportunity to reveal and disrupt the spectacle. A noted example of this was demonstrated within an Apple retail store in New York City.

In 2012, Apple had found itself embroiled in a high-profile media story around a spate of employee suicides at Foxconn factories. A major manufacturer of Apple products, Foxconn had caused outrage with their ‘solution’ of installing nets around their buildings to deter others doing so. In this case, those who had access to the AR app could view an image of a worker who had suicided lying on the ground of the retail store, surrounded by unaware Apple staff and customers going about their day.

As technology in this area improves, augmented overlays will soon become indistinguishable from the ‘real life’ image underneath [28]. Early examples of the new Apple ARKit featuring augmented objects that are dynamically lit using real-time lighting conditions demonstrates that this level of sophistication may not be too far away.

Tactical use of Existing Consumer Facing Augmented Reality Technology

In the spirit of the Culture Jammers ethos of tactical appropriation of available tools, the experiments outlined below have used a consumer facing, publically available AR browser. The aim of outlining these experiments is to demonstrate that creating AR take-overs is relatively straightforward and only requires a low-level of technical knowledge. The documentation also aims to detail what conditions work best, and what conditions are not favourable. All augmentations detailed have used the *Layar* AR browser.

The Layar Augmented Reality Browser and Layar Creator Backend

The *Layar* AR browser app runs on both Android and iOS devices and is free to download and use. Signing up as a content creator is also free, and provides access to the *Layar Creator* web-based backend. There are several levels of membership available, of which the premium subscription version allows the user to incorporate advanced features like Geo-Layers, video with alpha channel capabilities, and HTML iframes. While the premium level of access is required to produce more sophisticated geo-located interventions like the virtual *Occupy* protest in New York City, the basic level of membership provides a respectable set of features and operates through a low cost (currently €3 for thirty days access) pay-per-augmentation basis.

While not as comprehensive as the premium model, the basic augmentation package still allows users to overlay an existing target image with an impressive array of options including images with transparency, images with basic animations, basic video, audio, and hyperlinked objects. The basic augmentations in Layar work via an image recognition process. When a smart phone camera detects a ‘marker’ or ‘target’ that is found in the Layar database, it overlays user uploaded content in the smart phone display.

Selecting suitable targets to augment

As Skwarek outlines, one of the advantages of using AR is the ability to disrupt targets that would be otherwise difficult to access using physical methods. In the opening experiments outlined below, a local shopping centre was selected due to the variety of different panels found within one location and their resistance to physical takeovers. The nature of the advertising panels was also of interest, as the highly styled enlarged images create a hostile atmosphere for consumers with, or susceptible to issues related to negative body image.

Figure One: ***APPEARANCE DOES NOT EQUAL VALUE (Country Road)*** **2017 digital augmentation**

The first step in creating an AR take-over is documenting and preparing a suitable 'marker' of 'target' image. In a typical workflow, this would be the artwork file produced by a design or advertising agency, so when this is not available, it needs to be a good quality, unimpeded photograph of the intended target. Unless the photograph is taken at an exact perpendicular angle, it will then need to be corrected using image manipulation software (like Photoshop), and cropped to only include the target area.

The technique was successfully tested with an animation featuring the statement 'APPEARANCE DOES NOT EQUAL VALUE' augmented across a *Country Road* storefront (Figure One). In this case, a photograph was taken directly in front of the storefront and the image correction required was minimal. Once the marker image was imported into the *Layar Creator* interface, the application of the overlay can begin. For this outcome, an animated Graphics Interchange Format (GIF) file was positioned onto the storefront and the 'campaign' (as *Layar* defines it) was published and viewable to anyone with the *Layar* AR browser.

Other experiments in the same location were not as successful. A large hanging banner proved difficult due to the distance of the banner from the ground, and the angle required to view it. In this case, the browser could only successfully read the marker image from directly below. Another large window graphic could not be read due to spotlight reflections in the glass, and a final panel could not be tested due to intervention by a curious shopping centre security guard. At this point, the security guard advised that there was no photography allowed in the centre and further breaches of this rule would result in eviction from the premises.

Due to these difficulties, outdoor locations were selected for the next round of tests.

Using advertising distribution against itself

The first outdoor test proved a success in multiple ways. For this augmentation (Figure Two) a vacant billboard with advertising by the billboard company was used. This panel was selected due to the elevation and location within prohibited government-owned land, which would prove difficult for a standard physical takeover.

Figure Two: ***IMAGES THAT YOU COMPARE YOURSELF TO ARE NOT REAL (UN SEE THIS!)*** **2017 digital augmentation, two locations**

An animated image including the statement 'IMAGES YOU COMPARE YOURSELF TO ARE NOT REAL' was successfully augmented across the billboard. This particular augmentation was a paraphrasing of the statement 'images of people in the media are not real' which resonated and promoted critical thought in adolescent girls according to a study on their relationships to body image and the media [29].

Several weeks later, the same advertising message was chanced upon in a different location. The augmentation was successfully projected on this second location and from an alternative angle. This discovery reinforced that, like the BP logo hack examined earlier, the augmentation and target shared a parasitic relationship — while an advertiser pays for further physical distribution, any augmentation enjoys the same dissemination for the cost of only one.

Other considerations for successful augmentations

Figure Three: *WHAT TECHNIQUES ARE BEING USED TO ATTRACT YOUR ATTENTION? (H&M)* 2017 digital augmentation

Additional augmentations were executed to test different conditions and formats. The target image of the bus shelter selected (Figure Three) was taken during full daylight with the augmentation attempted at dusk. The AR browser did struggle to detect the marker in the different lighting conditions of the original image capture; however, a successful augmentation was finally achieved. The next morning, the location was covered in a blanket of fog, and the augmentation continued to display. 'WHAT TECHNIQUES ARE BEING USED TO ATTRACT YOUR ATTENTION?' relates to a lack of body image diversity in fashion advertising and is a statement designed to prompt viewers to critically deconstruct and evaluate the messages they see. Being aware of what you are seeing and developing a critical eye can work to reduce the influence of these kinds of images have [30]. The use of models of various ethnic backgrounds in the original advertising *suggests* diversity, but only perpetuates and reinforces an impossibly out-of-reach body shape ideal. This advertising is not about demonstrating diversity; it is about targeting a more diverse range of consumer.

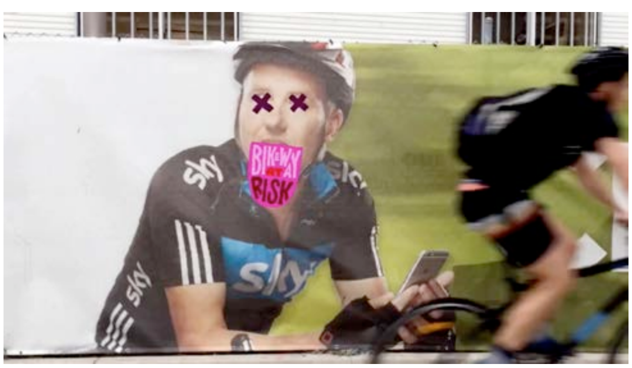

Figure Four: *BIKEWAY AT RISK* 2017 digital augmentation

Skwarek notes that the safety of the viewer is also something for the author of the augmentation to consider. This was reinforced via the augmentation shown in Figure Four. While testing, it proved difficult to stay focused on the physical surroundings and not wander onto the adjacent bikeway and into the path of a cycle commuter while viewing the augmentation. This façade covers the construction site of the Queens Wharf development in Brisbane Queensland. In a move that has caused concern with active transport advocacy groups, the development includes plans to convert part of the most utilised bikeway in the state into a mixed-use plaza and events space. Viewing the façade through the *Layar* app, an animated tongue appears exclaiming 'BIKEWAY AT RISK'. A video recording of the augmentation was shared on social media with links on how to submit objections to the development.

Legal considerations

While not as overt as defacing or replacing physical advertising, it must be noted that the use of the AR technology in this manner is not without legal risk. Augmenting a subversive message over a target image created by a third party will contravene multiple terms and conditions set by the employed browser. These breaches could result in actions ranging from accounts being disabled to prosecution from third party copyright holders.

As Skwarek explains, while there are no existing laws which specifically address the use of augmentations, he predicts that in the future "laws will be passed addressing image recognition and all the things it can affect" [26].

Activists using AR should make themselves aware of these risks and aim to protect their identities if this is a concern. Using Virtual Private Networks and pre-loaded credit gift cards can be employed to assist in providing some anonymity in this instance.

Discussion

The use of AR as a tool for subversion has several key benefits.

Firstly, alternative messages can be augmented to appear wherever target images exist. Depending on what that target image is, the distribution of the augmentation could range from a single specific site (such as the bikeway augmentation), to being viewable globally (such as the BP augmentation). Importantly, the amount of effort and financial cost involved for both of these situations remains the same.

Together with projected culture jams, AR can also reach locations that would be otherwise inaccessible if approached with a traditional physical replacement strategy. As more locations become hostile to protest and activism in general, this could prove to be a valuable benefit in communicating alternative viewpoints and messages.

The interplay between the overlaid message and the target it is augmented onto creates an interesting situation where the spectacle is both revealed and simultaneously viewable. As technology sounding AR improves and becomes indistinguishable with reality, this will become a move important intersection for culture jammers to explore.

This is not to say that augmented interventions will or should replace the more established forms of culture jamming. This paper has aimed to promote the benefits that AR can add to existing techniques.

AR also has limitations that should be considered. These include the exclusive nature of the augmentation itself, which is invisible to everyone who does not have the knowledge to point and scan with the appropriate app. A physical or projected image however, is far more public and inescapable of attention. It should be noted that the ability to simultaneously activate and document the augmentation allows for immediate distribution to a much larger audience.

Issues around safety of participants also needs to be further investigated and considered, as does legal ramifications that might affect the author of the augmentation. While the legalities of augmentations of this nature are still developing, there is no doubt that if this kind of augmentation becomes more popular, copyright holders and targets will aim to actively protect their images from augmentation in the future.

Conclusion

In this paper, I have outlined projects using three different culture jamming techniques (physical replacement, projected imagery, and AR projected imagery) for the purpose of exploring some of their associated benefits and limitations. While still in its infancy, the practice of using AR as a tool for creative disruption is already proving to be an exciting avenue for culture jammers to incorporate in their toolkit. The AR projects I have undertaken and described have aimed to provide a roadmap for others to build on, as well as demonstrate the potential for AR to be used in new and unique ways by activists interested in subversive communication.

Acknowledgements

Many thanks to the peer reviewers for their helpful suggestions, and to the AUC CreateWorld 2017 delegates who offered invaluable insight through post-presentation questions and other informal conversations during the conference.

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Complete Cinematic Immersion: Enhanced interactive soundtrack design for tabletop roleplaying games

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Abstract

Traditional tabletop roleplaying games offer a more agile, imaginative and physical experience than video games. The first tabletop roleplaying game, Dungeons and Dragons, has been popular since its creation in 1974 by American game designers Gary Gygax and Dave Arneson. The game involves players roleplaying characters while the Dungeon Master (or DM) describes the game's world, its narrative and controls destiny with a set of many-sided di. In recent years, DM's have been attempting to seamlessly integrate sound effects and music into the gameplay to create a more cinematic experience for the character players. This paper explores the efficacy of these attempts and suggests an improved method for the creation and control of interactive music to enhance cinematic-style immersion during roleplaying gameplay. Utilising Apple's Logic Pro software to explore conventions of film and game music composition, and Audiokinetic's WWise audio middleware for integration into game engines like Unity and Unreal, a final prototype iPhone app will be developed and demonstrated. This prototype has the potential to greatly enhance the Dungeons and Dragons game experience, but also has the capacity to be incorporated into myriad other table-top roleplaying games that exist on the market.

Keywords

music, composition, dungeons and dragons, Interactive, immersion, gaming, role playing, roleplaying

Introduction

Dungeons and Dragons (D&D) is a fantasy, tabletop, roleplaying game created in 1974 by Gary Gygax and Dave Arneson. The 5th edition, released in 2014, has recently enjoyed a global reincarnation in popularity [1]. A typical game involves players using their imagination - and a set of polyhedral di - to adventure in the imagination, to far off lands and/or worlds to fight, survive, rescue, explore and complete quests controlled loosely by the Dungeon Master (DM).

Compared to D&D, the Computer-Generated Imagery (CGI) of video games, its narrative, sound and music are all limited, in that they are pre-conceived. The audience is forced to experience someone else's imagination.

Dungeons and Dragons, however, relies solely on player imagination for almost all aspects of the game. The DM does not dictate narrative but is merely a guide, and player imagination cannot be expected to provide a soundtrack in the throes of adventure.

Music, in particular, is something of a subliminal dark art in the entertainment industries. It has existed since theatre and music collided in the early 1600s in the form of opera and is still used in the theatre to transition scenes, create mood, manipulate emotion, support narrative and characterisation, and play with time. This is also how music has always been implemented in movies. Even the *silent* movie is a misnomer, as piano, organs or even cinema orchestras always provided these aspects as musical accompaniment. Music's use and function in movies has now been fully implemented in the video game industry. Nowadays, immense Hollywood-style film scores accompany video games and function in exactly the same manner as cinema soundtracks.

To understand how music, as opposed to sound, is employed in movies one must understand the difference between diegetic and non-diegetic music.

Diegetic music accompanies screen action to enhance realism. For example, if the film audience sees a radio onscreen, they hear the same song on the radio as the characters in the narrative. Most sound elements in films work similarly, to add value to the on-screen reality. This is diegesis.

However, music in movies and games is generally non-diegetic; that is, it is intended for audience-only. Characters in the screen narrative do not hear it.

Additionally music's effect is also generally intended to be subliminal. Its effect is manipulative: subtly guiding the audience; helping them traverse narrative; controlling their emotions and physiological responses from moment to moment. The non-diegetic aspect of music, if implemented correctly, is key to creating a cinema-style immersive experience for the audience.

The use of non-diegetic music in D&D has been attempted, but has yet to live up to its potential. Currently, it is common practice for DM's to create their own cinematic music playlists to enhance immersion, yet the music cues do not necessarily match gameplay, enhance immersion or provide a sense of cohesion for the game. In fact, using the wrong music can break immersion, due to differing levels of volume, tempi, musical style, etc. Instead, engaging a fully customisable and interactive soundtrack would allow the DM to trigger appropriate non-diegetic music from moment to moment during gameplay, thus supporting narrative and enhancing player immersion.

Objectives

The aim of this study is to compose and test a generic, interactive soundtrack generation system for Dungeons and Dragons; the objective being to enhance gameplay through significant improvement of player immersion, just as effective, non-diegetic film music enhances the cinema experience for audiences.

Research question

The question posed is:

To what extent can an interactive, cinematic music soundtrack system enhance immersion in roleplaying games?

Context

Introduction

It is helpful to further contextualise some key concepts of this study: in particular, immersion, and music's traditional role in film. Dungeons and Dragons itself will be discussed in terms of its significance and success in recent times and the imagination's unique and powerful function in storytelling will also be discussed. Additionally, it is important to keep in mind that, in this paper, D&D will be used as a catch-all for traditional tabletop roleplaying games.

Immersion in Games

"Immersion means becoming physically or virtually a part of the experience…People play games for the experience that can only be achieved by engaging in the gameplay. In other words, a game's value proposition is in how it might make its players think and feel and 'fun' is the ultimate emotional state that they expect to experience as a consequence of playing" [2].

When an audience member feels as though they are a living part of the story they become immersed in the experience. Film and games use visual and musical cues to enhance emotional attachment. In D&D, immersion is created through the DM's ability to coax the imagination of the players and to encourage an environment, which allows emotional engagement with characters, story and player roleplaying. With the accompaniment of correct musical cues, this engagement could be strengthened, making the game more filmic in nature and greatly enhancing the players' experience.

Immersion in Film

Music "moves the plot along, it enhances the cohesiveness of the drama, it reflects what's obvious on the screen or what isn't: at it's best, it speaks to the deepest levels of emotion the audience is supposed to feel" (Bell, 1994). [3]

The emotional connection between music, narrative and audience is key to a film's success. It invites audience members to feel how characters on screen are feeling and reveal a subtle window into the film's central themes, symbolism, characters and even pose unanswered question. But music does not instruct the audience to feel; rather, it guides them and provides optimum opportunities for emotional engagement.

"Composers should stay open to what's possible, ultimately stay open in what compels you. Because all of us in the audience like it most when we are involved in the story" [4].

This describes cinematic immersion. And yet, while the storytelling aspect is effective in roleplaying games like D&D, the emotional immersion can be lacking when compared to film and video games. Players are being guided by the DM, whose primary role for the most part is that of verbal storyteller - not unlike the non-diegetic narrator in a play or a film. The DM cannot create the equivalent ambience and emotional depth of a musically scored film or video game.

"Storytelling is one of the most powerful ways to activate our brains, and roleplaying games do this incredibly well. When we tell stories, or experience them, our brains have to process language, the cause and effect of events, and also relate it to our own pre-existing experiences. While you're playing a roleplaying game, your brain is firing on all cylinders" [5].

The brain cannot then be expected to provide a musical soundtrack, while it fully engaged with roleplaying. This would have to be another job for the Dungeon Master.

1.4 Dungeons and Dragons Background Music Playlists

"Table-top games like Dungeons & Dragons or Pathfinder can be incredibly immersive with the right music" [6].

Currently, some Dungeon Masters use pre-compiled playlists of cinematic tracks. However, as the tracks have been pre-composed, they will carry with them contextual baggage from their source film or game and this may even lead to a break in player immersion.

1.4 DMDJ

One attempt to create an interactive music generation system for Dungeon Masters is the smartphone application, DMDJ.

DMDJ allows players to trigger music and sound effects, and even throw digital dice.

However, the application's implementation of music and sound tends to break immersion. It is too melodic in nature and, while the app's intentions are admirable, it attempts to provide the DM with too many options and has been criticized as "useless for any DM that's multitasking, which is all of us" [7].

The idea of a DM application that allows simple and seamless integration of customised music and sound into the game experience will likely be the culmination of this research journey. However, it is important to note that this paper details only the planning, creation and testing of the music and music generation system, not the finished application. It is expected that the implementation of the system into an application will be a relatively simple process, which will be outsourced to a game programmer.

Methodology/Methods

This paper includes both creative and analytical elements. The creative aspect combines qualitative, practice-based research methodology with grounded theory, as the conventions of Hollywood-style soundtrack composition and video game audio programming are re-applied to a new medium.

This project uses an action based research approach as defined by Kemmis and Mctaggart (2000) [8], as seen in figure 1.

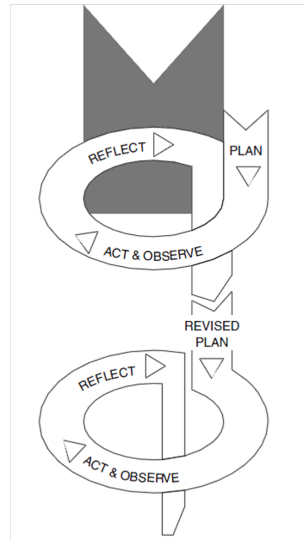

Figure 1. Action Research Spiral (McTaggart, Kemmis, 2000).

The action research spiral describes a planning phase, an act-and-observe phase and a reflection phase. Once complete, research is revised, and then the same three-phase cycle continues. In this paper, this methodology is used principally to test and refine the prototype interactive music generation system.

The planning phase involved the composition of the music soundtracks and the design of sonic atmospheres, created and recorded using Apple's Logic Pro X software. The tracks were made "loopable" and consistent with cinematic-style and music genres typical Dungeons and Dragons-style fantasies. Once the tracks were composed they were imported into Audiokinetic's Wwise, the industry-standard audio middleware for game integration into game engines like Unity and Unreal. Within Wwise, the tracks were edited to allow smooth transitions and interactivity using differing intensity settings. Next, the tracks were tested, refined to improve immersion, transitions and overall interactivity.

Ethical Considerations

The subjective creation, testing and refinement of the music and the interactive music generation system did not require ethical clearance.

Significance

An effective means to incorporate cinematic, interactive music into tabletop roleplaying games has yet to be achieved. The result of this practice-based study aims to change this situation with an effective interactive soundtrack control system for Dungeons and Dragons, or any roleplaying game. Additionally, enhanced interactivity and the incorporation of cinematic-styled music soundtracks into roleplaying games has the capacity to create new employment opportunities for composers, sound designers, audio middleware and game engine programmers and designers.

Results and Findings

Music Composition

The composition process was informed by the way Wwise integrates and controls music tracks. Each track needed to suit a specific world/environment; for example: a Forest track; a Cave Track; a Tavern track.

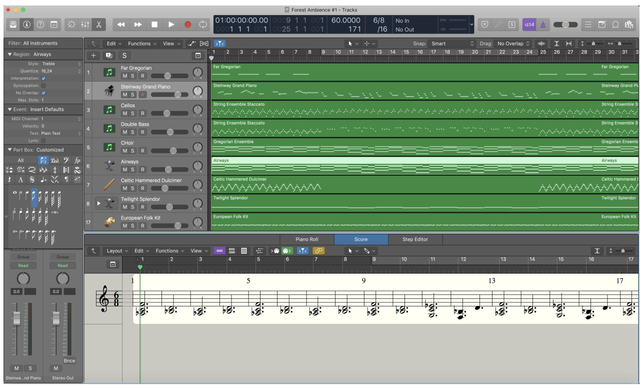

Figure 2. Creation of first forest track within Logic Pro X).

Video 1: https://youtu.be/FNMQpCPBlTo

The track used a consistent tempo and key and was multi-layered to allow for differing mixes with differing levels of intensity; for example: pads (calm); drums (building intensity); all instruments (maximum intensity). The tracks were also the same duration, so that they were loopable.

Musical Refinement

This worked well. However, in D&D, unlike computer game, scenarios and worlds are constantly evolving and rapidly changing and it is almost impossible to lock one genre of world to one track. For example, character quests may lead them into a forest but there is no generic forest, which can be associated with just one musical cue. Therefore, contrasting forest, cave and tavern tracks needed to be composed to allow for varying situations in the narrative.

Furthermore, unlike video games where players are controlling characters and solving puzzles on screen, D&D is extremely verbal in nature. Players are constantly trying to have conversations with each other, with non-player characters and even monsters. Therefore, soaring melodies, for example, which tend to be in the frequency range of the spoken voice, were avoided. Overly busy tracks too, could easily disturb immersion, and so this was complex rhythms and juxtaposed melodic lines were also avoided in all but the most action-packed musical cues.

Despite the fact that possible game scenarios are endless, four scenarios were composed to cover most fantasy-based game situations: Forest; Graveyard; Swamp and Town. Sub-genre musical variations were also composed. For example, the Forest genre includes four variations: Ambient; Dark; Elven and Wisps. Three variations for Combat were also created: Grim; Heroic and Vast.

Sound Design

Sound design was also required to simulate the cinematic experience. Accordingly, a multi-layered soundscape for each scenario was constructed by layering library sounds, recording whispering voices, distant screams, etc. and applying digital processing (such as "reverse") and fx plug-ins. For example, some synthesiser sounds were rendered/bounced, reversed and then Logic's convulsion reverb plug-in applied, and then also reversed, resulting in a completely new sound effect.

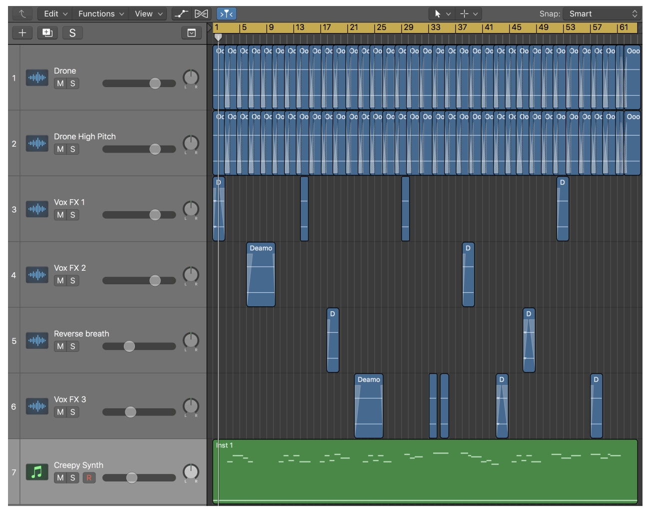

Figure 3. Creation of Music Audio Tracks.

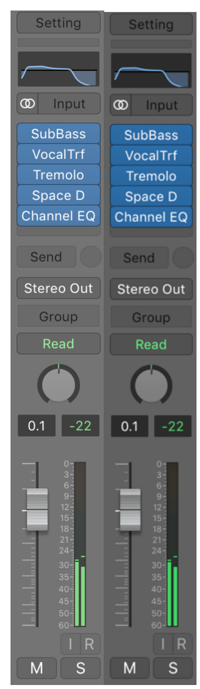

Figure 4. Different Audio FX.

Wwise Integration

Musical Intensity and the Thin Red Line

In Wwise, a red horizontal line was used to attach differing combinations of music loops, so that the Dungeon Master has control over the level of intensity within combat music, For example, in the combat tracks, a slider was implemented to control musical intensity, back and forth, until battle ended. Such a slider could be easily integrated into a smartphone application.

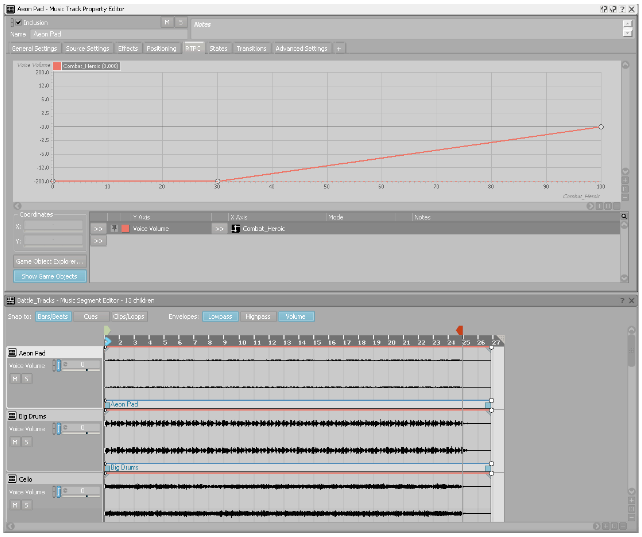

Figure 5. Horizontal Structure (intensity switch).

Randomisation of Background Music

Background music for differing scenes was imported into Wwise as A and B sections. Wwise was then programmed to randomly select sections, creating a perpetually adapting score.

Vertical 2: https://youtu.be/4F5lsJOU9Vw

Figure 6. Vertical Structure (A/B format).

All tracks – music and sound - were programmed programmed to loop until the DM felt the need for a change.

Track implementation within Wwise usually incorporated programming of tempo and duration tempo, as well cross fades to enable smooth transitions between tracks.

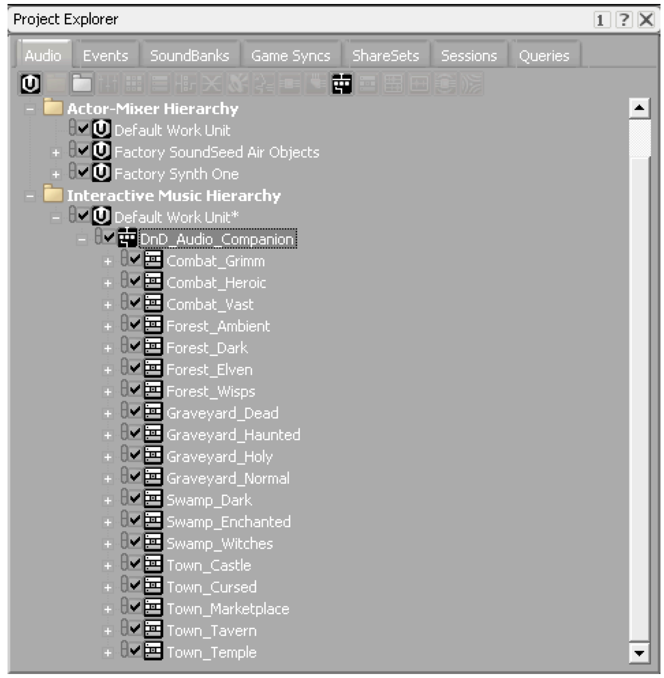

Figure 7. Audio Assets Within Wwise Music Hierarchy.

The combat tracks were mixed as individual instrumental stems. These were then attached to the intensity meter – the thin red line mentioned earlier - so that levels of intensity could be easily controlled.

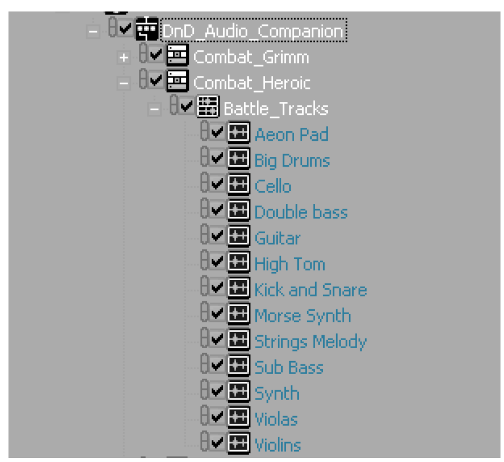

Figure 8. Individual Instrumental Stems Within Combat Music.

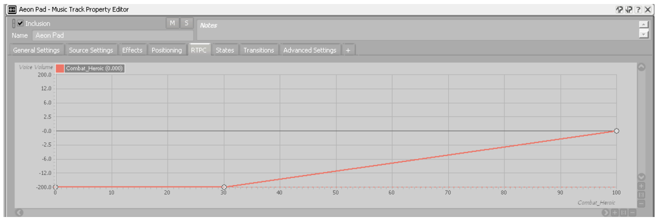

Figure 9. Wwise Intensity Meter.

Video 3: https://youtu.be/-EoL5MwAUaE

Once all the tracks were implemented into Wwise, the music had to be triggered at the correct times by placing them into “game states”. This way, the Wwise session can be given a programmer to plug-in to a game engine (typically Unity or Unreal).

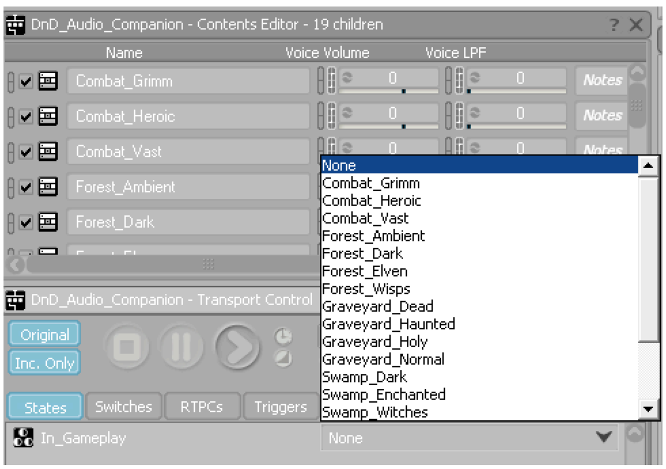

Figure 10. Audio Companion Sub-Genre Game States.

Video 4: https://youtu.be/KD06IxtAfFI

The Result

The resulting Wwise session synchronised and crossfaded perfectly. Refined background and combat music tracks were improved, being far more adaptive, less repeteitive and all intensity switches worked easily. Each world and combat sequence was sub categorized into correct game states to allow for simple game engine integration.

Conclusion

Using Wwise as the structural system for music and sound integration for a potential tabletop roleplaying game like D&D was relatively simple and effective. The resulting prototype is ready to be implemented into an improved DMDJ-style smartphone application. The final stage before releasing a “D&D Audio Companion” smartphone application will include user testing on Dungeon Masters and player characters to test and refine levels of immersion. It will be important that the eventual app is easy to use, does not interrupt gameplay for DM’s or character players and allows for players, composers and sound engineers to load their own music and sound into customisable worlds and scenarios, creating a new music and sound-centric community within the vast Dungeons and Dragons universe.

Video 4: https://youtu.be/UKEpu4vTFRk

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Using technology based devices to boost motivation when lettering by hand

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Abstract

The increased use of digital technologies to communicate using typing instead of handwriting has been attributed to the decline in handwritten communication. The paper argues that writing by hand is an essential skill to retain, with value beyond simply the technical ability to hand letter. Writing directly connects the hand to the brain and accesses the subconscious. Note taking by hand helps with memory and information retention. Free writing is therapeutic and unlocks creativity and using handheld tools improves manual dexterity.

Traditional approaches to improving handwriting typically involve repetition and continued practice. These methods, used extensively in education and skill-building exercises build muscle memory and knowledge. However, regular practice can be difficult to maintain, with motivation and also the increasing use of digital tools reducing the perceived need and desire to retain strong hand lettering skills. Motivation is a key factor, the repetitive nature of traditional approaches, such as writing drills requiring letters be written over again and again is often lost in increasingly digitally enabled, instant and interactive communication. In addition, the opportunities to create a handwriting habit are increasingly lost, as we have other ways to communicate.

The paper outlines current practice-led research exploring how to utilise and engage with digital technologies and tools to simulate a writing response rather than the typical typing response. Possible options to engage the learner are explored, to include, handwriting activities that comprise of practice in both conceptual and physical environments. Play theory using multi-sensory cursive writing apps for early education investigates how these apps use gamification, multi-sensory feedback and reward systems to engage young learners.

To then address multi-age, creative learners, exploring the use of pressure sensitive tablets and stylus to allow for the hand and brain connection to remain intact, as well as develop fine motor skills, along with building digital design tools competency with the addition of colour, brushes, pressure and layers typical to digital graphic design programs. These devices are also portable, enabling practice anywhere at any time. And finally exploring the use of virtual reality and augmented reality, allowing for an immersive experience and full arm and body engagement to create letterforms. Applications, both educational and creative based, for HTC Vive and the iPad create diverse tools and techniques, engage with practicing letter forms in varied and multi-sensory ways, engaging with haptic learning and play theory to encourage hand lettering practice, to consider how and what that means in the digital era.

Technology has impacted dramatically on handwriting skills and a decline in manual dexterity, legibility and penmanship where keyboard and mouse input replaces the need to write by hand. Handwriting has many recorded benefits, and has been a primary communication tool for centuries, but a key driver for the research is countering the loss of fine motor skills and access to memory and the subconscious for creative expression that the act of handwriting allows. As digital technologies and tools redefine how we communicate, the loss of handwriting can be countered, through using technology as a solution, engaging with emerging tools for a truly immersive, skills building experience.

Keywords

Handwriting, cursive handwriting, repetition, practice, motor skills, technology experiment and play

Introduction

The definition of technology constantly evolves, to consider the historical context, we can trace a timeline of how we develop and use the latest technology over the centuries, and the effect this has on the way we communicate. Written communication can be traced back to the earliest written documents from 3150 BCE, with impressed clay tablets from Sumer, to Hieroglyphic writing on papyrus 1450 BCE, writing on animal skins 160 BCE; to Roman rustic writing with a flat pen, to manuscript books that are lettered in scriptoria (Carter, Rob; Meggs, Philip B.; Day, Ben; Maxa, Sandra; Sanders 2014).

The writing styles and medium of communication we use evolve as new technologies are invented and adopted. These innovations expanded over time, responding to wider societal and technological shifts such as the Industrial Revolution, to allow communication to a wider audience with the invention of woodblock printing, the printing press and moveable type. Each new era, heralded a fear of the loss of traditional skills and methods, such as the Calligrapher’s unease when the typewriter was the new technology, to the rapid change of communication with technological progress and the digital revolution (Carter, Rob; Meggs, Philip B.; Day, Ben; Maxa, Sandra; Sanders 2014).

As new technologies come to the fore, others remain but their emphasis and use can shift, to consider the rise of computer technologies it has irrevocably changed the way we use tools for written communication. Long, thoughtful and constructed handwritten letters compared to the quick emoji's in an instant text have different behaviours of communicating the message but it is communicating and connecting all the same.

Although the research in this paper is based on, investigates the decline of cursive handwriting at the hand of the latest technologies, it also encourages the adaption of innovative technologies, alongside embracing the importance of writing by hand. It is inevitable that technology will change the way we communicate. However, the disappearance of handwriting, especially cursive, will alter the way we live today, with handwritten communication and how we remember tomorrow, in regards to handwritten communication from previous generations, legal documents or special occasion certificates.

WHY HANDWRITING IS IMPORTANT

Developing the skill of writing letterforms does not equate to finding a letter on the keyboard to press (Burke 2014; Stevenson and Just 2012). Handwriting is a complex task that uses meta cogitative, memory and motor skills, connecting the mind and body to allow ideas to flow and be expressed quickly (Kučera 2010; Bara and Gentaz 2011). A key consideration is that our haptic senses are not activated to the same extent when using a keyboard, as they are when we write letterforms with pen and paper. Motor memory is engaged as we need first to visualise the letter before recreating it as opposed to simply seeing a letter and pressing it (Bara and Gentaz 2011).

Moreover, the sensory experience that our brain encounters when writing also helps to retain information more effectively as multi-sensory tasks strengthen the memory (Patchan and Puranik 2016). Visual memory skills use cognitive ability to recognise and then reproduce the complex content of the writing system (Waterman et al. 2014). The ability to communicate and develop these processing skills through technical drawing, sketching ideas and handwriting are achieved by exercising the visual motor memory that regular writing by hand facilitates (Mon-Williams et al. 2015).

Cursive handwriting is a beneficial literacy skill connecting the mind, body and spirit in the act of writing. The fluency of cursive allows for idea generation to flow freely as fewer pen lifts enable writing at a faster pace. Lawrence Burke (2015) suggests that ideas can be recorded quicker in cursive than when writing a manuscript in print style or when using a keyboard.

Besides retaining information and learning, there are additional benefits to writing by hand, such as psychologically, where calligraphy and handwriting can create a relaxed state (Yang et al. 2010). Calligraphy, which means beautiful handwriting (D'Angelo 1982), is expressive of our personality and our individuality, allowing for creative expression. Once the involved letter components are studied, practiced and then mastered this will then allow for creative freedom. The skills required to execute these handwriting styles effectively are only achieved with practice and time allocated to learning the craft.

Communication is not only about the quick dissemination of information; it also involves expressing ourselves and with creative practice, creating a unique and original voice. Handwriting can be an effective way to represent who we are. By free writing or by streaming consciousness thought writing regularly, it is achieving direct access to our inner thoughts (Cameron 2002). It can be a therapeutic experience, as slowing down and taking the time to write by hand has been shown to have excellent mediation properties (Lomas et al. 2017). As technology changes the frequency of use and the perceived value of writing by hand, the loss of this skill and the benefits it provides need to be considered and valued.

"Language is the most intimately physically of all artistic mean. We have it palpably in our mouth; it is our langue, our tongue. Writing it, we shape it with our hands. Reading aloud what we have written - as we must do, if we are writing carefully - our language passes in at the eyes, out of the mouth, in at the ears; the words are immersed and steeped in the senses of the body before they make sense in the mind. They cannot make sense in the mind until they have made sense in the body. Does shaping one's words with one's own hands impart character and quality to them, as does speaking them with one's own tongue to the satisfaction of one's own ear?... I believe it does" (Burke 2015)

REPETITION AND PRACTICE IS THE KEY

As previously suggested, the reliance on the keyboard and a focus on technology for the use of the letterform creates a cause-and-effect scenario with the loss of the skill of handwriting. With the increasingly preferred method of learning and working via computers, such as paperless workplaces and schools (Robinson 2017), we are not writing enough to maintain the fundamental skills of legible cursive handwriting. A proven way to manage a fast and legible hand is by practicing on a daily basis. Handwriting instruction, consistent self evaluation, copying from letter models and using memory are all areas that will show improvement in the speed and legibility of handwriting (Santangelo and Graham 2016). This type of intervention has been identified as the most effective way to solve handwriting problems, as studies have found without practise little to no improvements are shown (Hoy, Egan, and Feder 2011).

To learn or to improve handwriting skills, one needs to practice the letterforms, through repetition, such as writing drills, copying and using memory, self-evaluation, to learn the technical skills of the letterforms. To be able to produce these letterforms instinctively and with ease we need to build muscle memory. The standard method to develop muscle memory is to repeat the letterform over and over again (Pfeiffer et al. 2015), for example, repeating a page of A's and B's and so on. This method of learning, (although useful, if using mindful practice), has the potential to lose the interest of the learner.

The Spencerian system of penmanship that was introduced by Platt R. Spencer, Sr. in the mid-18oo's (Spencer Authors 1874), is a method of breaking down the letterform into separate elements to practice and learn, to then combine into letters. This process of looking at the components of the letter separately was thought to be an easier way to comprehend the letter structure. This method engages with and builds mental competency as well as physical competency, as the mind traces the exactness of the stroke before the hand moves to execute the stroke (Spencer Authors 1874). Once comfortable in mind, muscle memory then allows for the practice of the movement of the strokes and builds manual dexterity.

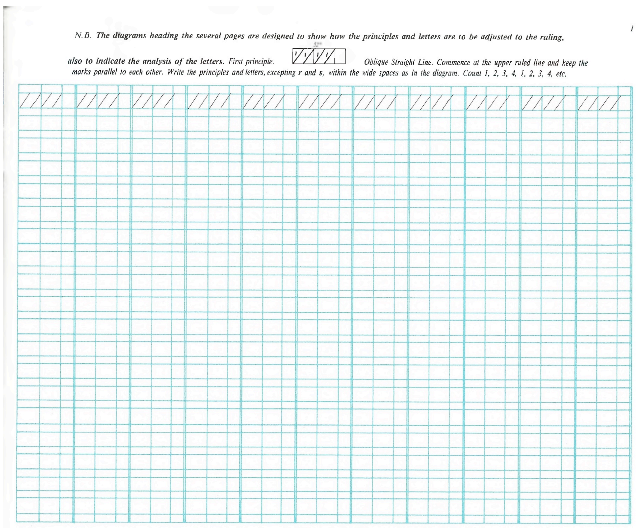

Figure 1. Theory of Spencerian Penmanship, Spencer Authors, 1874.

This process can seem tedious especially when presented with a copybook from the 1800's full of individual letters to be repeated over and over again. This method is proven as an incredibly effective way to learn the letterforms, as it is building muscle memory as the letters are repeated, however, if the student is not motivated by the passion of learning letters, the process can be perceived as monotonous. In an experiment the practice-led research this paper draws on found in a technology savvy demographic for example, the practice drills needed to be consistent of the correct letter formations studied in the copy book from the mid 1800's and introduced into knew environments both traditional and digital, to encourage regular practice.

WHY WE FIND IT DIFFICULT TO PRACTICE

We live in a world where technology is at our fingertips and increasingly integrated into many aspects of our daily lives. From the use of smartphones to computers, access to knowledge is just a click away, and we, in turn, can share our experience at the press of a button. Although we are immersed in technology in our school, work, and home life, the basic skills of handwriting are essential to retain (Dinehart 2014).

Cursive handwriting has become a technique that is used less frequently; with the shifting to technology and input tools such as the keyboard (Wollscheid et al. 2016). A small pilot study was run, when it was discovered that my sixteen-year-old son was unable to read or write cursive handwriting effectively. It highlighted a larger area to investigate, that primary and secondary students may be losing essential skills that cursive handwriting fosters. These skills that are developed when practising cursive handwriting include the ability to process a combination of attributes ranging from intellectual psycho-motor activity to learning with the mind, body and spirit (Burke 2015).

To review this within an international context, over 80 percent of American schools have elected not to teach cursive reading or writing (Sindelar 2012; Wollscheid et al. 2016) In paperless schools, students are encouraged to use emails to send work back and forth from teacher to student. As a result, handwriting through the use of paper and pens is increasingly removed from the learning environment as worksheets are typed out using keyboards and sent back via email to the teacher (Le Strange 2017).

We are fully immersed in technology at every turn, with our minds stimulated with information overload at the press of a button. We have access to information immediately and at times perhaps overstimulated (Robson 2017). The slow practice of calligraphy can provide time out, a quiet moment, and a slower pace; a relaxing mediating time writing (Chen et al. 2018). However, if results are expected quickly, outcomes may not be evident or able to meet the expected time constraints, without first putting in the practice (Hoy, Egan, and Feder 2011).

With the abundance of technology at our fingertips, opportunities to create a writing habit are disappearing. I personally still hand write a daily list but I would be interested in the daily list of a digital native (Wollscheid et al. 2016). I would imagine the process would comprise of the latest organisation app like Wunderlist or Evernote. These apps are effective, but also a simple example of the changing the way we record even our smaller daily tasks such as a handwritten list.

To consider the contrast of writing well-planned, refined content for a handwritten letter, to the immediacy and constant connectedness of emails, text messages or social media interactions, the way we communicate has changed and is vastly different.

PLAY BASED LEARNING AS A SOLUTION

Monotonous repetition has the potential to lose the interest of the learner, however, by undertaking play theory as a methodology, the research has explored a number of effective methods that address the mundane action of repetition through the use of technology. By using multiple sensory activities and personalised, project-based learning, one can be motivated to complete the otherwise tedious and monotonous practice of repetition.

There are three areas combining technology and writing by hand the research has focused on. These methods have identified potential solutions concerning the decline in writing by hand in a technological age. All three solutions use technology, while also embracing the act of writing by hand. These technologies enable enriched experiences as the connection from mind to hand is explored and not interrupted in the process by a keyboard or mouse. Innovatively engaging with technology and the range of new tools it allows can provide access to efficient methods that create availability for all and the ability to demonstrate self-expression with communication that connects a community.

TABLET FOR EARLY EDUCATION

There is an abundance of early education apps that engage the user on learning cursive handwriting on tablet platform. These apps use play along with multi-sensory feedback and gamification as a reward system, to entice the learner to continue with the monotonous practice of repetition to learn the letterform.

There are now a multitude of apps that can assist with learning literacy skills using touchscreen tablets (Neumann and Neumann 2017). Apps such as ABC Pocket Phonics analyse and aid handwriting skills, including alphabet tracing and activities that assist in the development of handwriting education (Walling 2014).

Apps to aid handwriting have been readily available on touchscreen tablets since their inception, and there is an abundance of these targeted apps to chose from. These apps assist with developing literacy skills to varying degrees, particularly those aiming to address the loss of cognitive function of the writing action previously restricted to pen and paper. As technology evolves the apps have become more sophisticated and able to more effectively mimic the pen and paper experience and handwriting skill development.

Exploring other technology-based alternatives to writing is extending technology past the keyboard. Equipment such as the touchscreen tablet and the invention of the Apple Pencil for Ipad or the Microsoft Surface Pro are all creating new ways to communicate visually that move away from the typical typing on the keyboard (Kim et al. 2016).

Technology in the classroom allows for individual creative learning but ultimately relies on the institutional system where a teacher-directed learning environment is in place (Kontkanen et al. 2017). A qualitative study exploring the role of technology in a high school classroom learning environment (Varier et al. 2017), shows the use of a technology-driven device, in particular, the iPad, encourages creative expression while enhancing communication. Using technology in a way that enhances learning such as using tablets for students to express themselves through drawing their ideas to communicate (Kim et al. 2016). This approach is fostering the use of picking up a pencil, perhaps an apple pencil, and writing by hand.

Together the tablet and handwriting apps are a suitable option for early education, however, not an appropriate option for a wider range of ages, or demographic such as a creative practitioner. A demographic that is seeking a more creative outlet, perhaps, may look for an option that can provide a realistic experience such as writing with a brush and using paint like effects with colour.

TABLET FOR CREATIVITY

Pressure sensitive tablets allow connection from mind to hand using a stylus instead of a mouse and keyboard. The tablet platform can create a sensory outlet for the user that allows for self-expression and creativity that more closely mimics the traditional pen and paper technique. Creative apps are resourceful opportunities to practice letterforms. With a range of realistic brushes available to download or creating the brush from scratch, the iPad provides another platform when practising and developing handwriting skills.

Tablets are also portable and allow for immediate access to practice, which can be used on the go and can fit into a busy schedule. Sometimes it is hard to accommodate regular practice, and finding these opportunities to practice are vital to handwriting improvement, even if it is twenty minutes a day (Hoy, Egan, and Feder 2011).

The development of creative apps for tablet devices and the use of a pencil introduce a multitude of choices for creative opportunities. An app that is representative of this is exclusive to the Apple iPad; Procreate. This app allows for content creation that could be compared to painting in Photoshop. Applications such as this have turned the tablet from a novel device to an essential tool in the designer and artist's toolkit. As technology advances, the ability for artists to engage with these tools to mimic traditional techniques make available what we have access to, today. With technology developing at such a rapid pace, continually creative tools are being made available. It is an exciting time to be a creative with the technology we have at our fingertips; the opportunities are endless.

VIRTUAL REALITY

There are many different styles of handwriting and with each style requiring different actions. For example, when learning pointed pen calligraphy, finger movements are used to create the body of the letterforms. When executing the loops on the ascenders and descenders, more of the wrist is in use. When creating large flourishes, the whole arm is in use, as there is more area to cover (Spencer Authors 1874).

This action is a similar movement to life drawing, as one stands at an easel drawing from the hip, using the whole arm. The scale of the technique is at play here. No matter what scale of the activity (from hand to full body movements), if the focus is on learning the movement and the strokes of the letterforms, we can start to play and experiment with a range of different platforms.

An exciting area to look at is technologies using creative apps in virtual reality (Thornhill-Miller and Dupont 2016). By experimenting with apps such as Tilt brush in virtual reality, one can practice the letterforms in an environment that uses an immense scale and depth. This action is similar to drawing at an easel by stepping into each stroke and using the whole body to create the strokes.

However, when writing in VR the user is not limited to the dimensions of the easel. This environment allows movement through space, using running writing, in a literal sense, on a significant scale. As previously discussed, memory is another essential factor to learning letterforms. Research shows by using motor memory rather than tracing the letters, uses more brain activity, in turn locking in memory (Steele et al. 2015). Virtual Reality apps such as Tilt brush provide a number of options, such as constructing the letterform by memory (without the use of guides), to importing personal resources and guides into the environment to trace.

Guides are helpful when writing out sentences to achieve consistency of height and angle of the letterforms. There is an opportunity to pull out grids with infinite scale options where the stroke locks onto the surface of the grid. Options to use grids or to write freely in the virtual reality environment are effective ways to learn the letterforms.

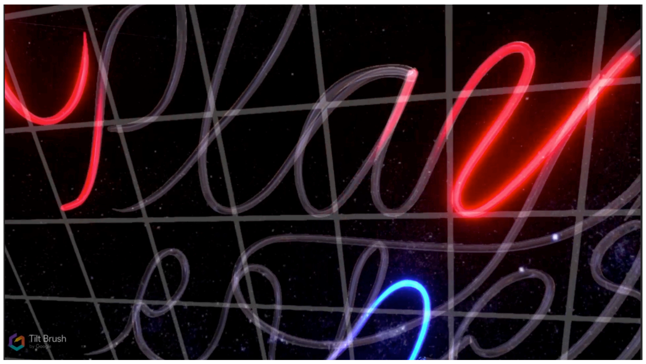

Figure 2. Elizabeth Reed, Practice in virtual reality, Tilt brush, 2017.

The pen to paper sensory experience is definitely lost when writing in virtual reality but is replaced with another experience. Freedom comes to mind, as there are fewer restrictions on writing in VR space. The resistance of the nib scratching against the paper fibres is a very tactile experience, whereas writing in VR is liberating and freeing without the limitations of scale and boundaries. These are very different experiences; however, both are using the bodies actions to build muscle memory and transfer information back to the mind to retain information of the letterforms. Writing in this immersive environment is creating an exciting platform to practice the mundane action of repetition. Moreover, it provides another area that can be utilised when using sensory rich activities to improve handwriting while enhancing the learning experience.

AUGMENTED REALITY

Another area the research has investigated is Augmented Reality. This latest technology allows the user to manipulate their live environment around them, easily accessible through technologies such as a smartphone app. It allows for immersive interaction and communication, where users can, for example, insert handwritten messages for others to find in their environment.

Apps such as Layar allows the user to create interactive augmented reality experiences with predesigned content and place them within an existing environment, the experience is augmenting or adding another layer to what is already there and is available to be discovered by others. Similarly, the World Brush app allows users to create their own content and leave messages in the environment for others to discover.

These apps are inviting users to interact with each other, connect with and ultimately communicate in an entirely new way. Writing or drawing by hand is an important factor of this new form of communication. Rather than relying on previous technologies such as the keyboard and mouse, both virtual reality and augmented reality has the potential to utilise practised motor skills combined with latest technologies, providing a reason for writing by hand to be valued, and the letterform to be practised.

CONCLUSION

Technology has caused a decline in handwriting in recent years, however, as the research seeks to demonstrate, technology can also be the solution. By using digital technologies to simulate a writing response rather than a typing response we see a regained interest in writing by hand, reimagined in digital mediums.

With the rapid changes driven by technology, particularly the immediacy of digital communication; providing information quickly and efficiently is a typical priority but delivering this content creatively to express ourselves is vital also. The growing availability of technology at our fingertips, with the virtual and augmented experiences that benefits from handwritten methods are reinventing ways to communicate by writing rather than typing. For this reason alone we should not step away from the traditional skills of writing by hand; in fact, as we move toward a more visual way of communication, now more than ever we should be putting pen to paper (in any of the mediums discussed) and valuing practice with our fine motor skills.

Improved fine motor skills, the ability to retain memory and the capacity to have access to our subconscious that stimulates our creativity, will be an invaluable combination for future technologies. The way we communicate has irrevocably changed; we have a range of additional digital tools to add to our creative toolkit. Due to the immersive nature of growing technologies such as Virtual Reality and Augmented Reality, writing or drawing by hand is an important factor of this new form of communication. The loss of skills and abilities the decline in handwriting has been attributed to (James 2017), could be recovered through the use of traditional skills combined with new technologies. Writing or drawing by hand is an important factor of this new form of communication.

Images

Figure 1. Theory of Spencerian Penmanship, Spencer Authors, 1874.

Figure 2. Elizabeth Reed, Practice in virtual reality, Tilt brush, 2017.

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Millennials, Politics & Visual Communication.

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Abstract
There is a growing decline in political engagement amongst young Australian voters. Simultaneously, we have a growing number of digital platforms designed to assist voters in making choices, understanding their preferences and ultimately – who to vote for. This paper explores a shift in response to the issue of political apathy, through the design of a new online platform. By moving the focus from political science to visual communication design, this new concept aims to engage a contemporary understanding of design activism as a mechanism of political empowerment.

Keywords
Political communication, design activism, millennials, visual communication, mass media

Introduction
It's not uncommon for young Australians to know more about the Kardashians than they do their local government. Although young Australians are keen to contribute to positive social change, they have limited faith in politics. They struggle to connect with politicians and don't feel like their vote has any impact on the issues that matter most to them.

When millennials are referred to as a consumer group, strategies for media communication are creative, progressive and powerful. However, when they viewed as a voting demographic… the focus often shifts to questioning why millennials are lazy, self-absorbed and apathetic. Hill explores the notion that informal voting among young Australians is an act of protest, in response to a lack of meaningful choice, and this is supported by comparative studies[1]. Enrolment rates for Australians between the age of 18-19 are low[2] and the AES reports that satisfaction with Australian democracy has been lower among young people for some time[3]. In response to these challenges, this paper is exploring:

- The low levels of political participation amongst millennial Australians.
- The application of technology and new media as a solution to improve low levels of political participation, and their impact.
- Disruptions to traditional political campaign systems and moving towards a demographic specific solution for political engagement.

Voting applications are new to the landscape of visual communication design, and often fall into non-design disciplines such as political science or sociology.

They contribute to the diversification and accessibility of information – which is a fundamental component of democracy. As these types of design outcomes appear online, continued research is needed to understand the implications and improve the quality and accuracy of the outcome

Out of Touch
The decline in political engagement among young voters is an international trend[4]. This paper explores this issue within the context of the Australian political system and millennial voters. Despite the availability of information online, the growing number of digital applications designed to assist voters – the decline continues to grow. In addition to the dissatisfaction with the overall voting experience, confidence in the Australian Electrical Commission is falling[5]. In 2016, the Australian Election Study survey revealed a record low level of voter interest, and record low levels of satisfaction with democracy and trust in government[6].

An impact of low engagement in a country with a compulsory voting system is the significant occurrence of 'informal voting'[7], also known as a 'donkey vote'. The significant number of donkey votes submitted in Australian elections is a repercussion of compulsory voting, sometimes seen as a simple strategy to avoid financial penalty[8]. While we can quantify the number of donkey votes identified as blank ballots, ballot papers with drawings or protest messages, how many votes are submitted with random or uninformed selections?

This paper combines both intentional and unintentional informal voting[9], when referring to donkey votes. It is reasonable to assume that voting without an understanding of how to do so correctly, can also be symptomatic of a lack of engagement in politics. It is also difficult to quantify the number of voters who complete the process successfully, but only make random selections to meet the legal requirement.

Survey data highlights that the millennial demographic is responsible for a significant proportion of donkey votes[10]. Hill explores the relationship between young Australians and informal voting, in relation to their lower levels of enrolment and turnout[11]. Low levels of millennial

[1] L Hill and Serrin Rutledge-Prior, "Young People and Intentional Informal Voting in Australia.," *Australian Journal of Political Science* 51, no. 3 (2016).
[2] Australian Electoral Commission, "Voter Turnout. 2016 House of Representatives and Senate Elections," (Australia: Australian Electroal Commission, 2016).
[3] Hill and Rutledge-Prior.
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[5] Ibid.
[6] Ibid.
[7] Hill and Rutledge-Prior.
[8] Ibid.
[9] Ibid.
[10] Ibid.
[11] Lisa Hill, "Increasing Turnout Using Compulsory Voting.," *Political Studies Association.* 31, no. 1 (2011).

engagement in politics is complex, however can be viewed as a combination of related factors, including:

- Cynicism about the Australian political system[12].
- Disconnection from political parties and increasingly low rates of party membership[13].
- Feeling 'out of touch' with mainstream electoral politics[14].
- Negative political attitudes[15].
- Preference for protest and alternative forms of societal participation[16].

Another possible source of intentional informal voting is a lack of trust in politics. A trend identified by political scientists globally, trust in political institutions and representatives is declining in most advanced industrial democracies[17].
As a response to the challenge of political participation, a range of technological platforms are currently available. Despite the benefits of these resources, political engagement among Australian millennials continues to fall[18]. In the following chapter, we will discuss a selection of these platforms and investigate what is effective, and suggest issues that limit their efficacy. Can we use their momentum to design solutions which lead us towards real change?

Digital Voting Resources

Interactive media and communication design strategies are increasingly being used to explore their potential for increasing engagement in politics. This chapter explores two online platforms, in addition to an example of political education design within a university setting.

The **ABC's Vote Compass** is a new online application designed to resolve the issues raised in the first chapter of this paper. One of the most commonly known applications in Australia, it utilises the largest survey data of voter attitudes ever undertaken in the country (1.3 million), helping its users to identify how their policy preferences align with political parties[19].

Despite its many positive attributes, we can assume that it isn't meeting the needs of disengaged voters – as their numbers continue to increase. One reason for this may be its lack of specific target audience. The designers of Vote Compass have an objective to stimulate democratic participation in a clear and accessible manner[20], however their target audience is unmanageably wide – and referred to only as 'the electorate'. In a review of Australian Voter Turnout, The Australian Electoral Commission highlights the need for focus on specific demographics, responding to complex issues surrounding lack of participation throughout society[21]. Critics of the platform question its accuracy[22] bias[23] and focus on specific policies[24].

Secondly, the Vote Compass development team contains a majority of social researchers, data scientists, political scientists[25]. This is logical considering the political content of the platform, and an obvious requirement of an outcome focusing on politics. But its primary use is *communication.* The platform is aiming to communicate complex information to a user group who are not accessing the same information from existing, available sources. Would Vote Compass be more effective if the development team included more communication design specialists? (One member of the team is identified as a 'designer', however a 'Google stalk' reveals that he is a recent university graduate, suggesting limited experience). If we assume that designers were consulted during its development, their lack of acknowledgement may suggest that 'design' and its related professions (interactive media specialist, communication designer, visualization designer) are not highly regarded within its production. A recent study of the Quebec iteration of Vote Compass indicated that it **does** have an impact on young voter's political preferences – however only for educated users who are already politically engaged[26]. When young Australian voters are disengaged to the extent that they aren't actively seeking the resources to assist with their voting issues, the challenge becomes complex and required a multi-disciplinary approach, beyond the limitations of political science as a practice.

Aiming to increase voter engagement and education using information, data and technology[27], the digital platform **isidewith.com** was developed in 2012. Peck and Boutelier have a professional tool kit of political analysis, tech marketing, user experience, data and analytics – much closer to the field of 'design' than the team behind Vote Compass, as demonstrated by its contemporary interface. Like all related voting resources, there are criticisms. Users of isidewith.com highlight the focus on policy at the exclusion of other elements, a drawback[28]. Like other tools with similar functionality, it also cannot take into account staffing changes within political parties, recent events that may change public opinion or the likelihood of a politician following through with an election promise[29].

Beyond using technology and the internet to impact political engagement, educators are experimenting with creative curriculum design solutions. In her introduction to politics course, **Wadsworth** has adapted her content and redesigned the learning experience around the theme of 'zombie apocalypse'[30] with success. She identified her student's numbness towards political

[12] Ibid.
[13] Hill and Rutledge-Prior.
[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] Ibid.
[19] Mazoe Ford, "Abc Vote Compass Opens," (Sydney: Australian Broadcasting Corporation, 2016).
[20] ABC, "Vote Compass," www.votecompass.com.
[21] Commission.
[22] Patrick Batchelor, "Why Abc's Vote Compass Doesn't Work for Me.," *The Sydney Morning Herald*, March 26 2016.
[23] Chris Kenny, "Media Watch Watch: Abc Vote Compass Fails to Find True North," *The Australian*, May 16, 2016 2016.
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[27] Taylor Peck, Nick Boutelier, and Andrew Karpiel, "I Side With," www.australia.isidewith.com.
[28] "Can't Choose? Try the Voting App.," *The New Zealand Herald* 2017.
[29] Ibid.
[30] Nancy Wadsworth, "Awakening the 'Walking Dead': Zo,Bie Pedagogy for Millennials," *Radical Teacher.* 107 (2017).

engagement, linking this with the understanding that her target generation has been the most quantified, monitored, medicated, micromanaged and assessed in history. Wadsworth links research and practice to understand her student's motivations; their apathy for politics is born from the feeling that there is no alternative to life in a materialist, consumerist society[31].

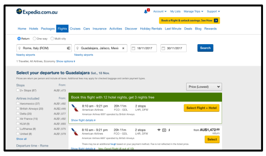
Millennials have grown up learning that the power to buy things is a greater expression of agency than direct political engagement, and economic growth is what keeps a nation strong. Wadsworth's educational design outcomes highlight the want and need for millennial students to understand theory concepts in relation to their agency in the contemporary world. Despite a much smaller 'reach' when compared to Vote Compass and isidewith.com, Wadsworth's example highlights the success that can come from designing solutions that meet the individual needs of a target audience, exploring new innovative solutions and applying design thinking within an educational context to create real change. Is it possible to combine the characteristics of these examples?

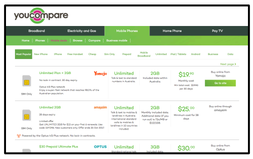
Despite the growing number of designed outcomes aiming to improve engagement in Australian politics, our participation is on the decline[32]. 2016 saw the lowest recorded turnout since voting was made compulsory in 1925[33]. Although this statistic indicates that the current voting applications aren't working, examination of them will create a foundation for future work in this area. By reframing the development of political communication tools into the field of design, we may start to see an improvement in political engagement.

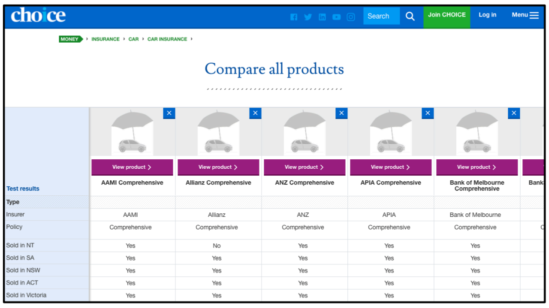
No Donkey dot org

The studio design practice associated with this paper seeks to explore alternatives to current political campaign systems, with the view to reengage Australian millennial voters. It aims to recontextualise commercial advertising strategies and embrace the current consumption habits of the target demographic. Rather than seek to reengage young Australian's into traditional forms of political campaigns, this research seeks to redesign the current political campaign content to suit the selected demographic. The first iteration of this is called www.nodonkey.org.

'No Donkey' aims to apply the format of existing compare and contrast websites, currently used by consumer platforms like www.choice.com, www.expedia.com and www.youcompare.com. These examples (pictured) successfully provide their users with complex product information in a usable format. All available options are identified in a side by side layout, according to the parameters set by the user. At first, this idea may seem simplistic, however the adaptation of existing design strategy for non commercial outcomes isn't often attempted. The familiarity that comes with this concept is also part of its strength. This concept isn't a viral social media campaign, it isn't a mass street protest, however forms of protest or design activism do not need to be loud to create impact[34]. One of the potentially significant outcomes of design initiatives such as No Donkey, are the growth of inner conversations and collective epiphanies regarding an individual's connection to their government and environment[35].







In addition to selected digital consumer platforms, 'No Donkey' utilises the systems of social media (predominantly Facebook) already widely adopted by Australian millennials. By designing new ways to communicate political information, in a way that responds to the needs of the user, No Donkey aims to increase political engagement through:

- transparent connections between political candidates and social issues.
- easily accessible information, without jargon, presented in a familiar format.
- the humanization of political candidates and direct access to their profile.
- visible connections between a vote and potential election outcomes.
- access to any changes or updates to a candidate's opinion or policy over time.

While there are existing platforms that aim to achieve similar results, nodonkey.org is unique in that it aims to engage a specific target audience; young Australian voters. Its functionality, layout and design will reflect the preferences of this target audience and will follow the traditional iterative design process to ensure its functionally meets the needs of its users. By connecting voters with a resource that allows for engagement in familiar and meaningful ways, we take a step towards a significant revolution in political campaigning – we are changing the way in which politics appears in the minds of voters[36]. It's no longer something distant or irrelevant, it's accessible and connected to everyday issues.

If millennials are unengaged in politics, why would they use No Donkey? Existing research indicates that Australian millennials **are** engaged in their communities and are motivated to contribute to positive social change. However, they struggle to identify with political candidates and don't feel like their vote makes a difference. They understand fake news and alternative facts, which create issues when this information is

[31] Ibid.
[32] Commission.
[33] Ibid.

[34] Micah White, *The End of Protest: A New Playbook for Revolution.* (Canada: Penguine Random House, 2016).
[35] Ibid.
[36] Ibid.

expected to contribute to an educated political decision. One aim of No Donkey is to provide information, without the filter of news media.

New resources designed to have positive impacts on voter engagement need to reconsider the relationship between the participants and the institutional structures. In 2004, only 82 per cent of Australians aged 17–25 were enrolled, compared with a national average of 93 per cent, and The (Australian) YES found that 45 per cent of Year 12 students described voting 'a waste of a Saturday'. The design and visual communication strategies utilised within the No Donkey platform aim to negate these issues, and link young voters existing motivations to current political systems.

Like the examples presented in the previous chapter, limitations have been identified during the early development stages. No Donkey cannot verify the honesty of a candidate. However, the increased transparency between a candidate and their policies over time has the potential to assist with voter decision making. The site also does not respond to the additional challenges faced by Australia's Indigenous population and other user groups with specific challenges. The platform is also dependent on a user's ability to access information freely through the internet, with suitable hardware and software.

When a business understands the behaviour of its target audience, it is able to apply this knowledge to its communication or advertising strategy, with the ultimate goal of increasing profits. One example of this is a recent study by Hall and Towers exploring the patterns of millennial shoppers and their decision making in a retail environment[37]. The research centers around the identification of a small, distinct target audience. It discusses the user's decision making process, expectations and preference for communication strategies. It also explores the changing landscape of consumption, from real spaces to the digital spaces. If this depth of research was applied to the previous examples of political communication design, would we see an increase in political participation? Can we apply the same engagement strategies to young Australian voters, and young Australian consumers? And what would happen if we combined this level of user group awareness and visual communication design strategy?

The perpetual development of technology requires business to actively engage in systematic improvement, research, redevelopment and refinement of its communication strategy (also known as advertising) [38]. However, this type of redevelopment and growth isn't currently visible within political communication.

Another contributor to lack of political participation is voters feeling unprepared to make a good decision. Perception of political competence can play a significant role in engagement, 48% of young Australians report that they do not understand 'political issues well enough to vote'[39]. How can this be so, when the Internet provides us with so much information, all the time? Without significant political-economic critique of media, limited research is available on how this is impacting specific target groups. What is the connection between the flood of available information and the lack of millennial political engagement?[40]. Forms of political communication are not reflecting the most advanced modes of communication technology, practice and 'information overload'. Technological advancements within communication industries are evolving rapidly, faster than traditional political communication systems are able to adapt. Working towards renewed solutions for political engagement may be more successful if framed within the context of creative industries, visual communication and design. A critical approach to the relationship between media and politics must be explored[41]. There is a clear link between age and voter participation, suggesting that we can target people under the age of 40 to increase overall turnout[42].

Future Updates

In democratic society, we assume that the public rules, but it can be argued that decision-making power resides in private hands[43]. If this is an accurate statement, the development of voter resources are not significant enough to resolve the issue. However, if we can increase the engagement of young Australian voters in our political systems, it has the potential to lead to significant change, revolution or disruption. When society is apathetic about politics, we aren't able to debate or take action when needed[44]. By changing the focus of political engagement from the context of political science to visual communication design, we can work towards creating effective solutions to the issue of millennial apathy and political empowerment on a wider scale.

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[38] Ibid.
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The Real Deal: An aesthetic comparison of modelled versus traditional guitar amplification technology

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Abstract

Since the rising popularity and widespread commercial use of the electric guitar in the 1950's, advances in guitar amplifier design and technology have played a key role in shaping the soundscape, tonal characteristics, recording methods and production styles of contemporary music. In recent years, digital modelling techniques have created new ways of producing sought after guitar amplifier sounds, which have changed the way producers, artists and guitar players use this technology both in the recording studio and in live performance. This in turn has impacted on how listeners, concert attendees and music consumers hear and experience recordings and live music. Extensive comparisons between authentic and modelled amplification have been conducted in industry magazines and online. However, these tend to be simplistic or overtly commercial in nature with typical yes/no style responses. A more rigorous approach is required which ascertains both gut feeling, as well as a more considered aesthetic response to the two technologies. This paper, therefore, presents a comparative study between traditional and modelled guitar technology that contextualises these amplifier sounds within fully produced music. It presents a non-biased quantitative and qualitative study of audience reaction to music - recorded using Apple's Logic Pro X software - which includes both amplification styles: authentic and modelled. The paper concludes with the results of the study and reflects upon the future of guitar amplification.

Keywords

Music Production, Composition, Apple Logic Pro, Aesthetic Amplifier Comparisons, Guitar Amplifier Technology, Line6 Helix, Amplifier Modelling, Tube Amplifiers, Survey Research

Literature Review

Traditional Guitar Amplification

Vacuum tubes (commonly referred to as "valves") were the dominant active electronic components used in guitar amplifier applications until the 1970's [1]. The distinctive tone of tube amplifiers was popularised

in the 1950's and 1960's by early rock and roll bands, making the sounds of traditional tube amplifiers a "standard" of popular music. The quality and degree of distortion in overdriven vacuum tube guitar amplifiers is widely considered to be musically pleasing, and responsible for the "warmth" perceived in an amplified musical timbre [1,2,3]. Many industry articles [2,4,5] claim that an amplifier is perhaps the single most important piece of equipment a guitarist uses to achieve their desired tone. Given that amplifiers vary widely in tonal character and in quality of distortion, professional guitarists typically require more than one amplifier in order to achieve a significantly wide tonal variety. However, a multiple amplifier set-up is by no means practical, due to the high cost, logistical requirements and the need for portable musical equipment. Demand exists for a more manageable combination of amplifier and speakers that is capable of producing/emulating the tonal behaviour of a wide variety of professional amplifiers, thereby eliminating the need for multiple amplifiers [5].

Figure 1: Front view of a modern built "Mesa Boogie" Traditional Amplifier Head

Figure 2: Rear picture of Traditional Amplifier Technology

Figure 3: Fender Bassbreaker combo amplifier

Modelled Guitar Amplification

“In the audio industry, the term ‘modelling’ usually refers to emulating or recreating the sound of something digitally” [6]. Amplifier modelling is the process of recording and then sampling various amplifiers and speaker cabinets. Several audio publications [1,7,8,9] credit Line 6’s POD device with igniting the popularity of amp simulations. Building on the AxSys 212, Line 6 garnered great success in the early 2000’s with the original POD digital amp modeller.

In the past decade, many manufacturers have toyed with modelling, as sampling and Direct Signal Processing (DSP) technology made it possible to emulate a virtually infinite range of amp and speaker combinations [8]. Complex algorithms have been designed to give ultra-realistic responses which simulate the nature of a “mic’d up” amplifier cabinet in different size rooms, with adjustable mic positioning and amp character that responds naturally to various articulations and techniques. Most “legendary” valve amps are famous for a particular sound or characteristic. Amp modelling can build on these by allowing further editing capabilities beyond that of the original [7,8]. Modelling allows users the flexibility to alter more settings than traditional amplifiers, such as equalisation, more gain, less hum, effects loop options and different speaker configurations, to name a few.

Figure 4: Pictures front and rear of Line 6 Helix modelling technology (forum.davesmithinstruments.com)

Advantages & Disadvantages

According to [9,10,11] the most common pros and cons of each amplifier technology are listed.

Advantages of Traditional Amplifiers

¥ Warmth and tone associated with vacuum tube design

The greatest example of a tube amp is the aforementioned tone; this is what has kept this technology in production.

¥ Natural overdrive

This goes along with tone; many guitarists favour the sound of an overdriven tube amp and find this far more satisfying than using distortion pedals.

¥ Responsiveness

Due to the nature of tubes, traditional amplifiers "respond" to each guitar player differently; these subtleties allow each player to create a unique signature tone with their valve amp.

Disadvantages of Traditional Amplifiers

¥ Cost

Tube amplifiers are more expensive than modellers and are costly to maintain. Tubes must be replaced over time; this can become expensive depending on the type of tube and amp.

¥ Weight and portability

These amps were originally built to withstand the rigors of the road and touring lifestyle. This hasn’t changed over the years. If not using a combo amp, an additional speaker cabinet is required to amplify the sound from the amp head [9].

¥ Volume

Tube amps need to be turned up to achieve the optimal sound of the tube. This makes it difficult to achieve desired tones at lower volumes [10].

Advantages of Modelling Amplifiers

¥ Flexibility and versatility

Amplifier modelling technology provides the player with an almost limitless tonal canvas on which to experiment [11].

¥ Size, weight and maintenance

In comparison to tube amps, modelling technology is compact and light. This makes modellers easily transportable, they also don't require tube replacement and maintenance.

¥ Consistency in sound

"Possibly the greatest advantage of modelling amplifiers is the consistency and ability to maintain tones/amp settings from the studio to the stage. The tonal qualities of modelling technology are less affected by varying room acoustics than traditional amplifiers" [11].

Disadvantages of Modelling Amplifiers

¥ Negative stigma

When digital amp modelling was first introduced to the market, the quality and sound was in many ways sub-par to that of traditional guitar amps. "Although significant advances in technology and design have been made, this has been a difficult label for modelling to shed" [8].

¥ Considered to lack "warmth and presence"

Many purists' will argue that modelling amps sound thin, sterile and lack the warmth and presence associated with tube technology.

¥ Programming difficulties

Modelling technology is often associated with being confusing and difficult to program, mainly due to the vast amount of options and parameter controls featured [9].

• Responsiveness

Guitarists often claim that playing through digital technology feels and responds differently to tube amplification [8].

Existing Knowledge

[9] Cites two professional societies who have the most to say on this subject: the IEEE (Institute of Electrical and Electronics Engineers); and the AES (Audio Engineering Society). Both of these professional groups publish peer-reviewed journals, with articles written by engineers and scientists who work in the professional and consumer audio industry, as well as in cutting-edge academic research. Marcus Ryle, and Michel Doidic (two former Oberheim Electronics designers) are the creators and co-founders of Line 6 modelling technologies. Their design research claims to have taken into account electrical engineering studies from societies such as the IEEE and AES, as well as drawing upon their experience as electronic designers, specialising in synthesisers and audio effects at Oberheim Electronics.

The Debate

[12] suggests the real debate regarding traditional versus modelling amplifiers arose when respected professional musicians began using modelling technology in live and/or studio situations. Industry experts and content creators/writers for respected audio companies such as Music Radar, Sound on Sound and Mix Online attribute this period to the early 2000's.

Comparative Studies

The primary reason for comparative analysis is to gain a broader and greater understanding of current knowledge on a given topic. Accumulating existing knowledge from various researchers/societies helps to place this information into context, allowing further advancements in technology, research and development to be made.

Common Methods

Existing research and comparisons between these amplifier technologies have predominantly been collected through frequency and amplitude response tests; also results attained through A/B blind audio testing [8]. The Cambridge English Dictionary defines this as "a scientific test in which the people being tested (or the person testing them) do not know what is being tested." This test method prevents results from being influenced by any prior information and aims to rule out subjectivity. To increase the level of accuracy with blind testing, this can be expanded to include an ABX test. The ABX test employs the use of three sound sources: A, B and X. X is the same as either A or B, but not disclosed to the listener. This test concentrates on identifying if at all any difference exists between the sounds in question.

Negative Reaction to Common Methods

The main issue concerning negative views towards blind test methods is in relation to the level (i.e. quality) of hearing skills of participants involved in the study. Questions surrounding the listener's ability to consistently critique and compare two sound sources nourish an ongoing argument between audiophiles [12]. Variables associated with quality of playback systems used for testing are also considered to be problematic with this method. [13] Draws the conclusion that there is a need to place standards on persons partaking in blind testing research, and believes that quality control measures should be implemented before considering results of such testing. For example, testing trained listener cohorts separate to un-trained listeners would produce more reliable results than testing both groups at once. He validates this statement by mentioning how the listener has both answers available to them; implying that some answers could be guessed, rather than based on merit.

Comparative studies in Differing Creative Industries

A recent publication [14] details the use of traditional versus modern technologies in the film industry. This was a study involving aesthetic reactions to film captured on analogue film versus digital video. Three short narrative films were produced with an analog as well as a digital camera. A cinema experiment with 356 participants tested whether the three film versions are perceived differently. It is also interesting to note that other industries such as the film, photography and media sectors have made comparisons between traditional and modern technologies in their specific fields.

[15] analyses the technology used to shoot the top 100 US grossing films since the year 2000; providing statistical data of movies shot on traditional film, versus those captured digitally. Follows extends the scope of his research to include comparisons on which particular film genres are represented by each cinematography method. Follows implies this shift towards digital filming methods is a direct influence of the versatility that digital technology offers. Deakins (as cited in [16]) states "Shooting on digital gives me a lot more options. It's got more latitude; it's got better color rendition, It's faster. I can immediately see what I'm recording". The clearest benefit of digital cameras is the immediate result. There is no time-staking process of handling the film, sending it to a post-house and watching dailies in a screening later [16].

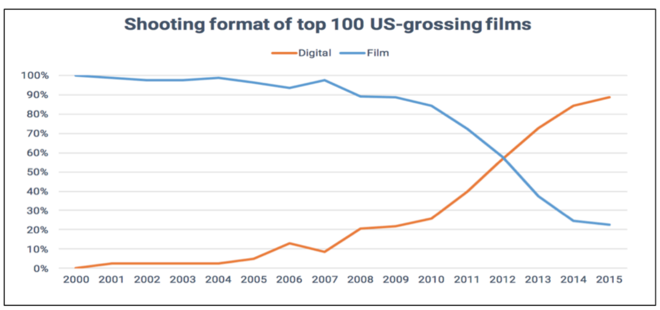


Figure 5: (Top) Chart shows percentage amounts of films captured both on film and digitally between 2000-2015 (Follows, 2016).

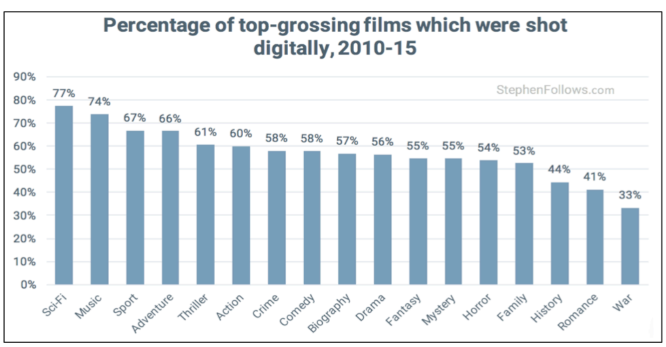


Figure 6: (Below) Details percentages of film genres shot digitally between 2010-2015 (Follows, 2016).

As opposed to cinematography, the music industry is yet to produce such detailed studies comparing analogue and digital technology of guitar amplifiers.

Gap in Knowledge

YouTube contains numerous comparisons and various tests of analogue versus digitally modelled amplifier technologies. One of the most prominent YouTube video channels regarding this subject is Anderton's Musicians TV Channel. Anderton's are responsible for hundreds of videos on guitar and amp technologies, many of these dealing with comparisons relevant to this research. One problematic issue concerning Anderton's content is how results are measured through the perspective of guitar players, not informed through opinions of an audience. A shortfall of this is the tendency to focus on "feel" and the "responsive nature" of the amplifier technologies, rather than gauging how each technology sounds in context of a musical composition; which is how an audience (as opposed to a player) will experience this technology.

Summary

This literature review has explored the existing knowledge of aesthetic comparisons between traditional and modelled guitar amplifiers. The research question for this study identifies a need for further comparison and analysis of both technologies in the context of recorded and fully produced music.

Research Question(s)

The main research question of this study was:

What are the similarities and differences between aesthetic reactions to modelled and traditional guitar amplification technology?

The following sub questions were also explored:

Can audiences differentiate traditional from modelled amplification?

Do audiences have a preference for one technology over the other, and why?

Aims & Objectives

The purpose of this research project was to gain insight into the technological aspects and aesthetic comparisons between "traditional" valve-driven tube amplifiers and "modern" modelled digital amplifiers. Listed below are outcomes this research aimed to achieve:

- An understanding of the aesthetic comparisons between both amplifier technologies;
- A comparative study of the two amplifier technologies within music composition, rather than performed by the solo guitarist;
- Qualitative questions using survey methods distributed to a wide-ranging audience.
- Quantitative data of the audience's aesthetic reactions, and preferred method of recording.

• Survey confidentiality, which aims to provide un-biased results, further adding to existing knowledge of this topic.

Methodology & Methods

Theoretical Approach

This critical inquiry study has employed a post-positivist theoretical position. [17] Affirm that "today's practicing quantitative researchers would regard themselves as post-positivists; accepting that there is an independent reality to be studied, but that all observation is inherently fallible – we can only approximate the truth, never explaining it perfectly or completely." Post-positivist research lays emphasis on inferential statistics with insistence on assigning probabilities that observed findings are correct, not certainties [18]. "Critical inquiry Is the process of gathering and evaluating information, ideas, and assumptions from multiple perspectives to produce well-reasoned analysis and understanding; leading to new ideas, applications and questions" [19].

Methodology

The methodology used for this project drew upon Anderton's blind testing comparisons. This can be categorised as grounded theory and practice-based research. "Practice-Based Research is an original investigation undertaken in order to gain new knowledge partly by means of practice and the outcomes of that practice" [20]. Through my inclusion of A/B testing which that is not judged/assessed by the performer (person playing the amps and writing the music) I will be furthering Anderton's experimental methods.

Grounded theory is an inductive methodology. As described by [18] this is "the systematic generation of theory from systematic research". Grounded theory is a qualitative research approach originally developed by Glaser and Strauss in the 1960's. This method begins with the raising of generative questions, which help to guide the research - although they are not intended to be either static or confining [21].

As the researcher begins to gather data, core theoretical concept(s) are identified. Tentative links are then developed between theoretical core concepts and the data. This project has adopted techniques from grounded theory and survey research, providing a distinct foundation of qualitative and quantitative results. The study has examined qualitative data gained through survey methods; allowing quantifiable insight of differing audience's aesthetic experience of both amplifier technologies, within a musical context.

Methods Outline

This practice-based study has utilised an objective exploratory investigation to determine the preferred method of guitar technology (in terms of sound) across differing audience cohorts: the general public, musicians; and guitar players. The study has integrated musical composition and recording of three instrumental tracks, with two versions of each track being mixed and produced: one consisting of traditional amplifiers mic'd up and recorded; the other featuring recordings from a modelled version of the same amplifier, speaker cabinet and microphone.

Figure 7: Recording of traditional guitar amplifiers with microphones in a recording studio (Australian Music Magazine).

Figure 8: Pod Farm digital software as used in DAW'S (GuitarSite.com).

Once my original compositions were written, recorded and produced into two separate versions (a mix with each amplifier technology) they were then condensed into short excerpts, uploaded to YouTube, and embedded into a survey. I decided to use SurveyMonkey to create and distribute my research survey. They are an online survey development company specialising in customised survey creation. SurveyMonkey provides data collection, data analysis, brand management, and consumer marketing for Facebook, Virgin America, Samsung, among others.

The purpose of my survey was to gauge the audience's subjective aesthetic responses in relation to the guitar sounds heard in each excerpt. By implementing specifically designed questions, which span through multiple sections of the survey, I aimed to produce a diverse range of results. Various sections include; A/B test questioning, full composition excerpts, isolated (guitar only) excerpts, preference/favourite mix questions and a musical background/industry page. Results determined whether the general public (as opposed to musicians and guitarists) could differentiate traditional from modelled amplification, to ascertain whether or not the audience had a preference for one technology over the other. This research also aimed to inform my own creative practice as a musician, guitarist and producer.

Qualitative Strategy

Qualitative research is concerned with the opinions, experiences and feelings of individuals producing subjective data. It describes social phenomena as they occur naturally and understanding of a situation is gained through a holistic perspective [21]. The qualitative strategy for this project was survey research.

Quantitative Methods

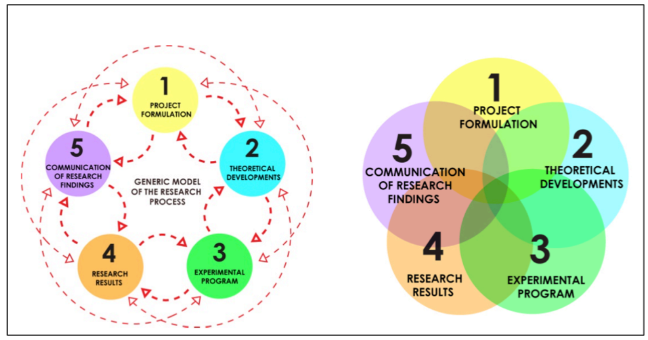
Measuring survey data was imperative to the outcome of this research project. Results and statistics attained through participant's answers provided a quantifiable solution to the research question.

Experimental Design Methods

Listed below are aspects of this project which outlined the experimental design and practical applications within my research:

- Choosing modelled amplifiers, speaker cabinets and microphones that I could access in tube/traditional forms.
- Recording guitar tracks with a line level signal (Direct Injection or D.I.) in order to re-amp the same performance/take at a later date in the professional studio.
- Ensuring all mix aspects (drums, bass and other instrumentation) remained the same through the course of the mixing process; especially when both versions were mixed for the final time before mastering.
- Any additional (post-mixing) plugins and editing used on guitar sounds had to be applied to both forms of guitar amp technology for the recordings and purpose of this research investigation.
- No external hardware (distortion, effects and modulation pedals) were used. If Digital Audio Workstation (DAW) effects such as reverb or equalization were applied, they were duplicated in both mixes (ensuring the exact same settings were used).
- Each song was mixed and mastered identically, with the exception of the amplifier technology used.

Framework of Key Processes



Figures 9 & 10: Generic models of the research process depicting possible iterative moves and interdependencies between phases (Bonollo & Hoyos, 2013).

Project Formulation

This primarily involved formulating the research problem. Initial planning of the project concept, including research into the current knowledge of the topic was conducted. "The literature review informs the researcher of what is known and not yet known about a given topic" [19]. Project formulation also defines implications of the project within its field.

Theoretical Developments

[22] Claim that once informed through the literature review, the researcher can formulate the gap in knowledge and define research aims and objectives. This leads to theoretical developments and determining design components for the project. These developments include conceptualising, theory building and modelling based on the findings of the literature review [23].

Experimental Program

This was the stage of the project where artifacts and experimental works were created and the work/study conducted. This drew upon the research plan developed throughout the conceive phase.

Research Results

Results were informed through data collection and analysis.

Ethical Considerations

One ethical concern regarding the outcome of this investigation was how survey results may favour a particular amplifier technology over the other. This project's conclusion could potentially be damaging to amplifier manufacturers and brands; it could also disprove claims made by such companies (i.e. that modelling technology is on par with traditional amplifiers) whilst my findings could possibly reveal otherwise. However, by composing original music for my comparative study, I established control of ethical issues surrounding authenticity, alleviating problems concerning copyright/ownership of the music. Furthermore, as these compositions were new, there were no prior connotations regarding the music (from the audience perspective) and therefore would remain unbiased in terms of past context. Human ethics approval was granted from the Human Research Ethics Committee (HREC). In line with ethical standards, confidentiality, respect and privacy of participants and organisational staff was preserved at all times [24].

Results and Findings

This section presents findings from the final collection of data attained through my online survey. Overall, more than 180 participants completed all of the questions and various sections, allowing different aspects of the research question to be analysed and discussed. Specifically, the following questions established from the literature review were considered:

- What are the similarities and differences between aesthetic reactions to modelled and traditional guitar amplification technology within music production?
- Can audiences differentiate traditional from modelled amplification?
- Do audiences have a preference for one technology over the other, and why?

Qualitative Data

Aesthetic Reactions

After summarising the focal viewpoints expressed by each respondent, I was able to group the "core" aesthetic reactions/preferences into descriptive categories.

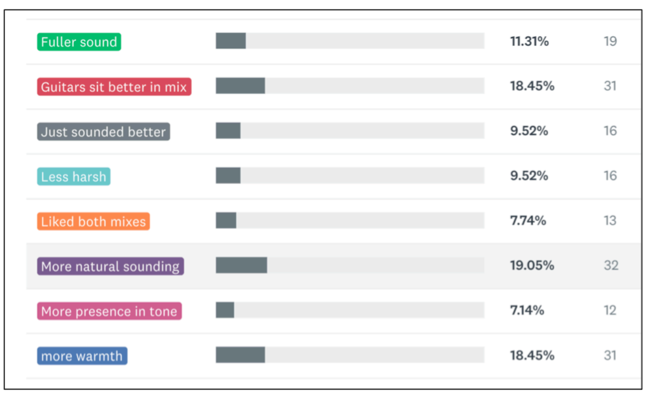


Figure11: Keywords used by participants to describe their selection for the preference mix question (Keko, 2017).

Although these descriptive categories did not reflect the type of amplifier technology employed in comparison to comments, an indication as to what audiences prefer most in terms of aesthetics could be distinguished; the top three reasons being: more natural sounding, more warmth and guitars sit better in the mix.

Differentiating Between Technologies

Means used to test participants' ability in differentiating between amplifier technologies consisted of three separate methods: full composition excerpts; isolated guitar excerpts and A/B audio testing. Each excerpt was directly followed by a sub question that asked respondents to select how confident they were when answering. Data reflects there was no statistical significance to suggest the audience could differentiate "modelled" from "tube" amplifiers; all three sections ranked within a 47%-53% division for both technologies. Further testing and a higher numbers of participants may assist in revealing a more significant difference in this statistic. However, one consistent trend which was evident throughout this entire section, was the selection of the answer "50/50, (thought about choosing both answers/technologies)" being the most common response.

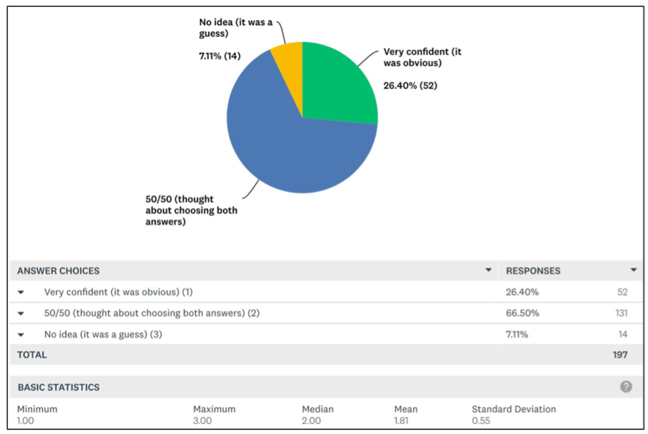


Figure 12: Graph reflects data measured in participants confidence when selecting answers throughout this section (Keko, 2017).

A/B Test Question Summary

This page included a total of 3 separate A/B audio questions. Each question contained two audio files of exactly the same song excerpt, which were listened to in context of fully produced music (including other instrumentation; drums, bass, etc.). I decided to mix the answer possibilities to include all available variables: modeled followed by tube technology; tube followed by modelled technology; and both excerpts using the same technology/mix (e.g. A/A and B/B). Using the A/B audio test method was in my opinion the most logical way of discerning whether or not audiences could pick the difference of both mixes/amplifier technologies.

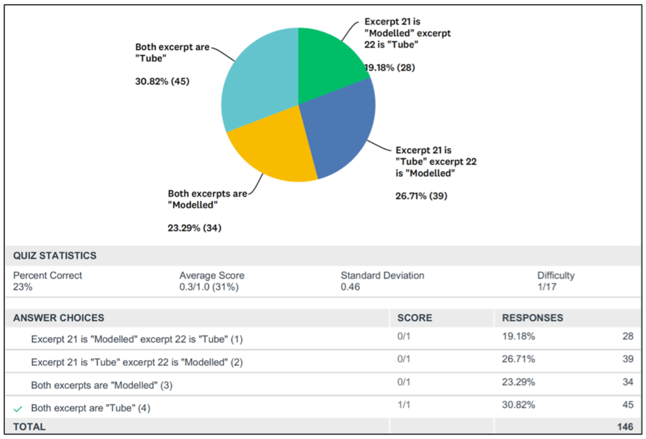


Figure 13: Displays % of selected answers for the "trick question" added to my survey

Preference in Amplifier Technology.

Through the inclusion of a preference mix question in my survey (disguising the type of amplifier technology heard), it was possible to calculate a percentage, which represented "preference" for each amplifier technology. Again, the data shows an almost 50/50 split between both amplifier technologies.

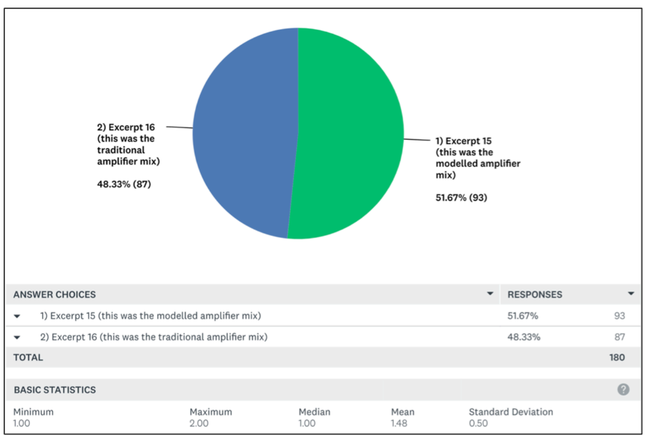


Figure 14: Pie chart depicting preference % for both types of amplifier technology

Quantitative Data

Cross-tabulation Analysis

Quantitative data was produced for this project by implementing cross-tabulation statistical analysis. "When conducting survey analysis, cross tabulations are a quantitative research method appropriate for analysing the relationship between two or more variables. Cross tabulations provide a way of analysing and comparing the results for one or more variables with the results of another/others" [25]. The scope of my research was limited to comparing these demographics with the overall percentage quiz score for the entire survey, I recommend that future studies expand this approach by investigating the data from various survey sections. For example, comparing demographics with the preference mix answers, there are indications that suggest younger participants prefer modelled mixes.

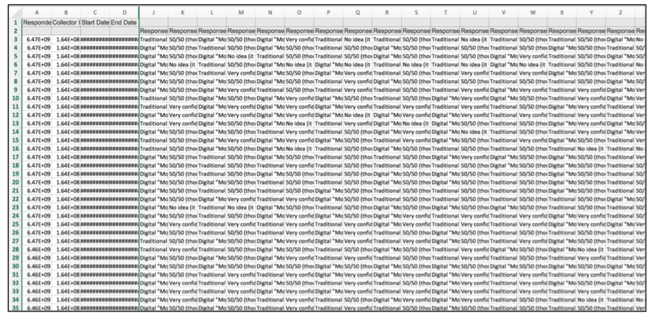


Figure 15: The beginning of the Microsoft Excel spreadsheet containing all of the extracted data from SurveyMonkey

Age statistics

It was established that the highest scoring age sector in relation to overall quiz score statistics, were participants from the 60 and above age bracket. This indicates a possible correlation between older respondents and the possibility that they are more familiar with traditional technology than younger participants; therefore, they have shown to differentiate between the two technologies more effectively.

Demographics: Age Groups	Score on Survey
17 or younger	44.00%
18 - 29	47.65%
30 - 44	46.84%
45 - 59	46.72%
60 and above	52.33%
Did not answer	34.61%
Average Overall Survey Score	45.51%

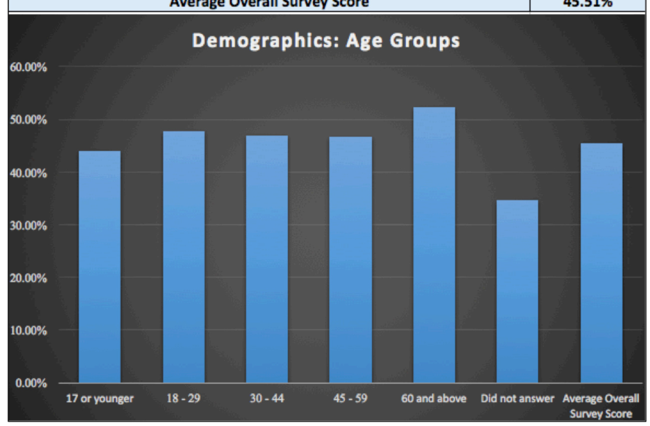


Figure 16: Graph presenting overall survey score % of respondent age demographic

Musical Background Statistics

An unexpected finding was that participants who held no background in music or production/studio experience, managed to accomplish the highest percentage of survey success.

This could suggest that guessing was more effective than discerning differences between the two types of amplification. It could also suggest that untrained, un-biased individuals were able to answer without musical pride or musical opinion clouding judgments, resulting in a better overall success rate.

Demographics: Musical Background/Training	Score on Survey
Brief background in music	43.11%
I know absolutely nothing about music	56.00%
Little to no musical background	49.25%
Relatively good (somewhat experienced)	48.22%
Very good (professional)	46.25%
Did not answer	34.61%
Average Overall Survey Score	**45.51%**

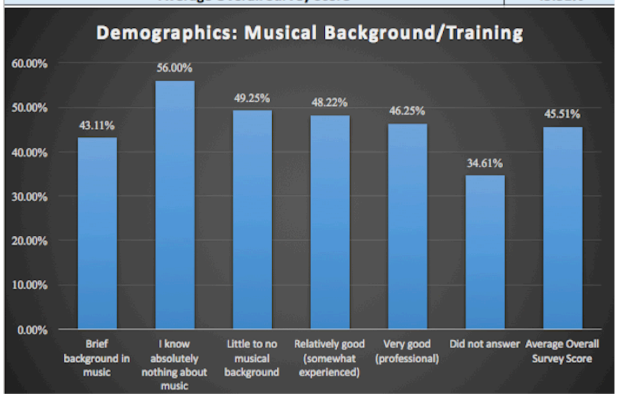


Figure 17: Shows a comparison between the musicianship levels of participants in relation to the overall quiz success %

Music Industry/Employment Statistics

The data attained from this particular demographic supports the suggestion of "participants guessing can score similar, or higher results than respondents who have a professional background/training in music.", as the highest scoring sector are respondents who worked in the music industry, but not as musicians, studio engineers/producers.

Demographics: Music Industry Employment/Experience	Score on Survey
No Music Industry Experience	44.83%
Musician (but do not play guitar)	42.86%
Musician (guitar player)	48.08%
Studio engineer/producer	48.91%
Work in the music industry: Not as musicians, studio engineers/producers	52.29%
Did not answer	34.61%
Average Overall Survey Score	**45.51%**

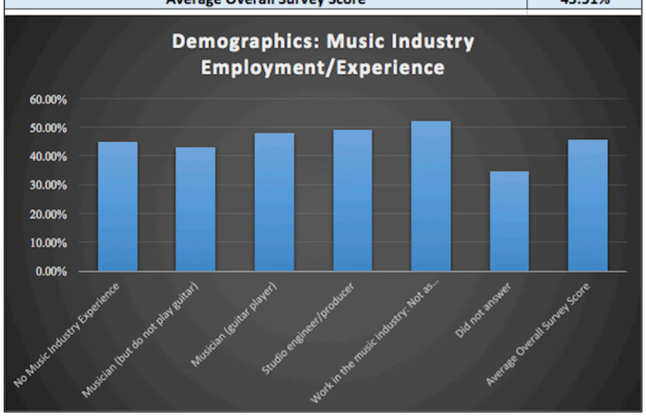


Figure 18: Graphic representation of the quiz success % compared between demographics related to music industry employment/experience

Guitar Ability/Amplifier Experience Statistics

Again, the demographic with beginner level experience has achieved a higher overall percentage in the survey quizzes than expert guitarists. This again suggests that a novice guessing may gain higher results than an experienced expert guitarist. This seems to confirm that even experts cannot discern the difference between the two technologies.

Demographics: Guitar Ability/Level of Experience	Score on Survey
Beginner guitar player with no experience using guitar amplifiers	41.00%
Beginner guitar player with some experience using guitar amplifiers	50.00%
Have learned/played guitar at some point, no longer currently playing	47.00%
I answered no to the previous question	46.38%
Intermediate level guitar player with experience using guitar amplifiers	47.97%
Professional level guitar player with broad experience using guitar amplifiers	45.88%
Did not answer	34.61%
Average Overall Survey Score	**45.51%**

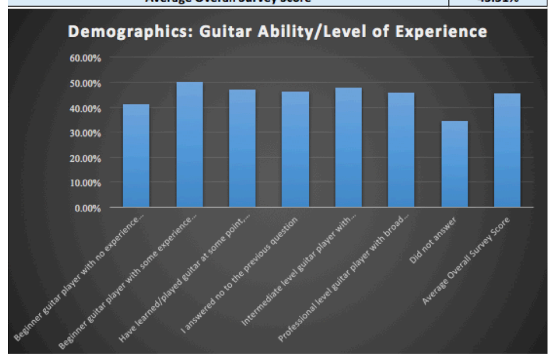


Figure 19: Comparative analysis between levels of guitar ability/amplifier experience and the overall survey success rate

Conclusion

The results of this study suggest that audiences of all ages and differing levels of musical expertise cannot differentiate modeled versus tube amplifier technology in the context of produced music. Participants who claimed to have no experience in playing guitar and using amplifiers; were ironically, consistently the highest scoring demographic throughout this survey. Whether such participants had a more objective and unbiased approach to listening and answering the questions is a possibility. However, even taking this anomaly into account, average percentages of correct answers for all participants, including a high percentage claiming to be professional musicians and producers, was only 45% (7.5 questions correct out of the total 17). Furthermore, findings did not demonstrate any statistical evidence to conclude that audiences can differentiate between modelled and tube amplifier technology, even when heard in isolation. This validates the hypothesis: that amplifier modelling technology has improved to the point where audiences – both expert and novice – can no longer distinguish between authentic tube and digitally modelled amplification technologies.

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Conceptualising Game Design – A Tangible Approach

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Abstract

Conceptualising and communicating game design ideas amongst teams of game developers can be an enigmatic process. Designers of video games often rely on rapid prototyping and iterative approaches to creating game play experiences. Deep and meaningful experiences are not always easily expressed in the form of words and as a result, initial design intentions are often misinterpreted and or poorly communicated. This often leads to designers of games relying on serendipitous approaches as they intrinsically move toward design intentions. These approaches are largely derived from traditional models of agile software development which place little emphasis on the cognitive process of individuals in the development team. Therefore, approaches based in theories of cognition are rarely considered for designers of games. One such area of this field is tangible design which attempts to investigate links between cognitive science and the physical tactile world. The impact that tangible approaches have on collaborative game design is yet to be thoroughly investigated.

This paper describes a practice-led study that aims to test the influence of tactile 3D printed video game assets on cognitive processes and design communication for teams when conceptualising game designs. This is achieved through a review of existing literature in the field, followed by an in-depth analysis of a tangible approach to game level design. Through this process the study presents a deeper understanding of the implications that tangible design strategies have on conceptualising and communicating game designs.

Keywords

Game Design, 3D Printing, Embodied Cognition, Tangible User Interfaces, Tangible Interactions, Design

Introduction

The craft of game design involves decision making [1]. However, articulating these sometimes-complex design mechanics, puzzles or problems amongst team members can be challenging, and design intentions may not be fully realised without clear and concise methods of communication and strategies for collaboration. Current methods of verbal communication are challenging due to the idiosyncratic nature that pertains to a designer, that of which words are sometimes inadequate to describe. John Dewey an American philosopher, psychologist, and educational reformer describes this as *"language fails not because thought fails, but because no verbal symbols can do justice to the fullness and richness of thought"* [2]. Studies such as Kim & Maher [3] *'The impact of tangible user interfaces on spatial cognition during collaborative design'* investigates the application of cognitive science to tangible interaction systems through a constructivist approach. This study indicates potential opportunities for tangible approaches to enhance design practice. This paper reports on a study that investigates the role of game designer, specifically examining the implications tangible mediums such as 3D printing can have on the design and creation of video games.

Methods

This research will be an empirical practice-led study; that is, the study is introduced into practice and carried out through practice [4]. It responses to the proposed question using an action research cycle framework as outlined by Kemmis-McTaggart [5]. This involves the practitioner to plan, act, observe and reflect on their practice to then implement into the next cycle. This study will be based off a reflective framework as described by Schön in which he states that reflective practice as the practice of which the practitioner becomes aware of their indirect knowledge and learn from experience [6]. Schön divides his reflective practice into two distinct areas of reflection. Reflection-in-action: to reflect on the immediate experience as it happens and Reflection-on-action: a retrospective analysation and evaluation of an experience [6]. Carole Gray describes Schön's reflective based practice as an important concept to allow arts and design researchers in to have a closer and further attachment to their study [4]. The aim of the cycles of practice is to design and develop techniques, workflows and prototypes informed by reflection. Rosanna Hertz describes reflection as *"To be reflexive is to have an ongoing conversation about the experience while simultaneously living in the moment"* [7]. Therefore, a research journal will be utilised to record gradually shifting methodologies and restructuring analysis of objectives during development [8].

This study will comprise of the collection of qualitative data through an indirect observation of a set experiment which involves tangible vs computer-based design session. The data collected form the empirical foundation of the study which establish the insight into the cognitive process during design within the context of game development.

Game Design and Collaboration and Cognition

Computer game development has often been viewed as *'technical development'*; this is due to the interweaving nature of video game design and programming languages [9]. However, video game development has an array of different skills sets that may be required, including, but not limited to: 3D modellers; concepts artist; and game designers. The previously mentioned roles are well defined in the industry; however, the role of a game designer is still seen in its infancy stage and is undergoing a process of *formalisation* and *professionalisation* [9] [10]. However, despite the indeterminacy, game design theory and philosophies can converge into an umbrella term that can best describe the role of a game designer as a *'Technical Communicator'* [9]; someone who can articulate methodological and in-depth information.

Embodied Cognition Theory

To allow for a clearer communication of methodological and in-depth information a deeper understanding of the cognitive process of game design is needed. One epistemological view in cognitive science is referred to as Embodied Cognition Theory. According to Foglia & Wilson [11] the mind is grounded in the details of sensorimotor embodiment. That is, what we do in the physical space can help us process: knowledge, attention, memories, judgment, and evaluation, reasoning, problem-solving, and decision-making, linguistics.

Tangible Interactions (TI) - A Brief History

Tangible Interaction Systems

This theory of cognition has seen empirical evidence through the form of tangible interaction research. The term *'tangible interactions'* is a generalised description that is used to describe the research on how humans can interact with physical objects to manipulate digital data, see figure 1, below. Tangible interaction have seen rapid growth since the concept was explored during the 1990's, and is now seeing significant interest from large corporations such as Microsoft and Philips Design [12]. The research area of tangible interactions first became notable in 1997 by the notion of *'Tangible User Interfaces'* by Hiroshi Ishii and his team at MIT Media Lab [12]. Ishii built his works on prior knowledge in Fitzmaurice's [13] 'Graspable User Interfaces' which explored the notion of a physical user interface. In Fitzmaurice's research, he concluded that a participant's natural ability to touch, texture, and make gestures demonstrates a performance boost to the given task [13].

Research in tangible interactions systems holistically do indicate that more studies are needed in order to improve it's understand in the learning environment. However, the underlying concepts and research into tangible interactions illustrate that comprehension may be able to extend from physical activities. Therefore, a more suitable alternative tangible approach to game design may be needed.

Figure1. Reactable Tangible User Interface (TUI) [21]

3D Printing Technology

3D printing is an emerging technology that is gaining a great deal of traction. This emergence has resulted the changed of how companies and consumers manufacture or buy products [14]. The process of 3D printing is described by Campbell, Williams, Ivanova, & Garrett [14] in six separate stages, see figure 2 (below). The 3D model can be constructed then exported in a majority of computer-aided design (CAD) software or 3D modelling programs such as AutoCAD, 3Ds Max or Maya. Additionally, these programs are widely used in the video game industry. Therefore, little training would be needed if 3D printing were to be introduced into the video game development process [15]. Stereolithography (.STL) file is an industry standard 3D printing file format that approximates the surfaces of the 3D model with triangles [16]. The model is sent to a slicing software that determines the model cross-sections which then controls how the printer head layers down the material [14]. If necessary, supports materials are printed to hold up any overhanging structure and to prevent deformation [17].

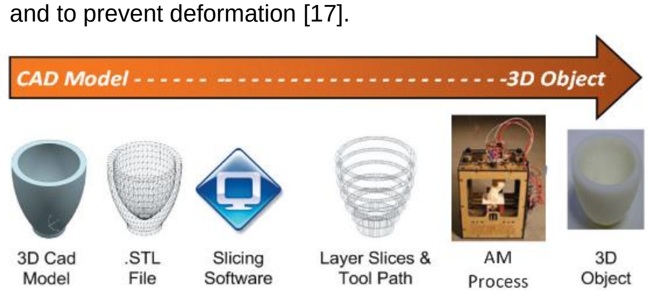

Figure 2 - Generalized Additive Manufacturing Process. [14]

Current uses of 3D printing span across an array of different industries, from automotive, aerospace, medical, education, architecture, film, animation visual arts and video games [17] [14]. However, there is limited research that demonstrates practical usages for 3D printing within video game development and more specifically, *technical communication*.

Design and Development

The design and development of tangible design techniques took an iterative approach. The initial development was to create perceivable 3D printing game assets to be used in a tangible vs computer-based design session. The design incorporated the modular design principles outlined by Mader [18] in *'Creating Modular Game Art For Fast Level Design'*. The models were designed using defined grid lines, and adopted the power of two principles [18]. This approach provides designers with the ability to build environments (including general assets, e.g. character models or barrels) without the underlying doubt to whether the assets will line up. Schöns notion of 'situativity' was incorporated into the design. This cognitive approach to designing can be described as a constructivist view that emphasizes the designer's situational environment and context [6]. Therefore, developing physical assets that can be perceived by game designers as digital game assets is essential.

Reflecting on this approach revealed several challenges in the original design intention of the creative outcome. The first challenge is due to the nature of how addictive 3D printing is achieved. The left model in figure 3 demonstrates that printing in that orientation the print head can easily lay material on top of each other. However, due to the grains running horizontally the extruded dowels becomes weaker and are prone to breakage when in use. Printing the platforms on its side, as demonstrated on the right model, provides a stronger build due to the continuing flow of material that is being laid down. Thought, further clean-up of each asset is needed due to the support material needed to bear the overhang that is created when printing in this orientation. Additionally, this way of 3D printing can be inaccurate as the material can bend and warp before it can fully settle.

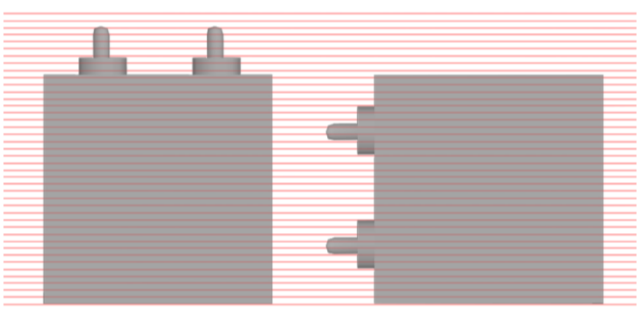

Figure 3. Example of additive 3D Printing. Red lines indicate direction of print head

Secondly, when testing and exploring the result, it felt cumbersome and unintuitive. The process of setting up the boards and connecting them took longer than expected, and unexpected difficultness of plugging platforms in and out of the perforated board broke the immersive experience. From my observation this experience may be linked to the notion of *physical fatigue* [19], a problem that can be present is tangible user interface; however, further research is needed to confirm this hypothesis. As a result, I believe these complications undermines Schöns constructivist views of designing in situational context and environment [6]; as well as the notion of 'Embodied Cognition Theory' as mentioned earlier [11]. To address these issues a second cycle of practice was performed that focused on: an alternative approach to the tangible design environment that feels more intuitive; and further the development of assets that are functional in the computer-based environment to develop a game prototype.

Alternative approaches led to the uses of magnets to attach to the platforms onto a whiteboard instead of the 3D printed dowels in a perforated board. This serendipitously resulted in the opportunity to use a whiteboard to allow for annotation or notes during a design session. This meant that the tangible construction pieces where not used in the final design in the final design.

For the second objective of this cycle, I explored the uses of the Unity game engine and how it can be used to facilitate the computer-based game design session. The Unity design session test scene was set to 2D mode; this was to reflect the genre, 2d puzzle platformer, and to reflect the tangible design session. When importing the models into the program some models displayed bright highlights due to the default Lambertian style shaders. To rectify this complication a light blue/grey shader with low metallic (specular) values were applied to soften out the highlights and print detail of the model, see figure 4.

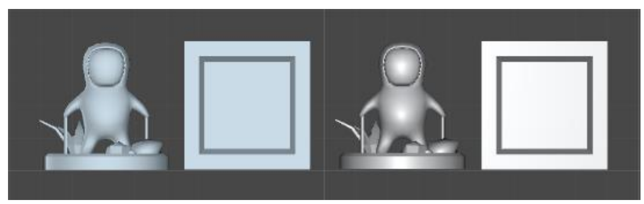

Figure 4. Custom Shader (Left) Default Shader (Right)

In reflection on the second cycle of practice, the process of creating, exploring, and experimenting with the physical objects this time felt more intuitive. This was achieved replacing the dowels on the platforms with magnets and rejecting the perforated board in favour of a whiteboard. As a result, I was better able to perceive the 3D objects as platforms and how they connected to one another. Also, the audible feedback when connecting the platforms to the whiteboard added to that understanding. Furthermore, the reduction of objects also led to a reduction towards physical clutter, thus allowing for a smoother workflow. This experience from my observation is further linked to the notion as described in 'Embodied cognition theory' that is, the sensory and motor function plays an important part in cognition [11]. Consequently, I believe this redesign further supports the constructivist views of designing in situational context and environment.

The third cycle of the study was to test the different behaviours that come about when designing using tangible or computer-based objects. The design sessions were focused towards developing a 3D puzzle platformer game prototype within 30mins. The end goal is to have two prototypes, one tangible and another computer-based. A total of six participants were involved in the study. They will be placed into two groups of threes and ask to respond the following brief:

Develop a 3D puzzle platformer prototype using the available tools.

The game prototype must contain the following:

1. *One puzzle that requires two moves/action to solve.*
2. *One puzzle that requires three moves/actions to solve.*
3. *Additional puzzle that with any amount of moves to complete are welcomed.*

The objective for this cycle was to investigate the implications:

1. That a tangible design process has on the craft of designing games

The participants were asked to design using tangible game objects or a traditional mouse and keyboard on a desktop computer. In the tangible environment, the participants used a large whiteboard that was mounted to the wall and the 3D printed assets to design the prototype. Also, the tangible design session could utilise whiteboard markers for notes or annotations (see figure 5). In the computer-based environment the participants developed their prototype using a typical mouse and keyboard set up on a 15-inch MacBook Pro; additionally, a TV was connected to the visuals could be seen easier. Both design sessions were video recorded in a typical office meeting room.

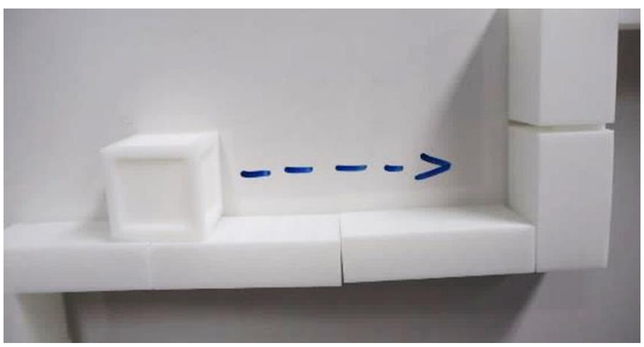

Figure 5. Annotation Being Used in the Physical Design Session

Results

Using the three cycles of practice as a voyage to the final creative outcome. The purpose of the design session was to contrast the different behaviours that emerge when conceptualising game design thoughts within a tangible and computer-based environment. The creative component of this study is to address the research question - *can 3D printed assets can be used as a tangible interactive design technique for video game development? If so, how can game designers apply this to the 3D puzzle platformer genre to enhance the development process?*

Techniques & Game Prototype

Cycle of practice one and Cycle of practice two of this study was to explore different design techniques and to develop a pipeline for 3D printing in the game development process. It was clear in the first cycle that the process of 3D printing game assets at that level needed further investigation. In the design and development cycles of practice, I found that printing fine detail such as the perforated boards on an Up Box+ 3D printer is not meet the needs of this study. This is including the use of ABS over PLA which is more appropriate due to its structural integrity and its suitability for mechanical designs. This made the original idea of interconnecting boards, clips, platforms, and legs not viable as the printed results did not provide the accuracy and reliability needed for this project.

The final creative outcome that was used in the study included 22 tangible and computer based assets (see figure 6 & 7):

1. Platform Long
2. Platform Short
3. Platform Ends
4. Platform Slope
5. Hanging Chains
6. Spiked Floor
7. Flag Pole
8. Bouncy Blob
9. Springboard
10. Arrow Sign
11. Gem
12. Main Character
13. Enemies
14. Bomb
15. Explanation Mark Crate
16. Locked Crate
17. Generic Crate
18. Barrel
19. Lever
20. Key
21. Locked Door
22. Asterisk (Wildcard)

Figure 6. Sample of 3D Printed Assets

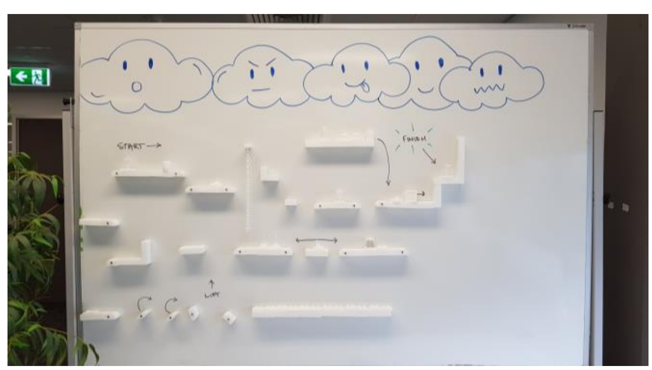

Figure 7. Platforms Used in Example Session

Design Sessions

Upon investigating the implications that tangible design has the craft of designing video games; it was clear that different behaviours transpire from when designing using different mediums. It was interesting to observe that the initial response from both groups was to approach the task significantly different. During the study the participants in the tangible design group began the session by discussing strategies on how to approach the design problem; by familiarising themselves with the three elements that were in the design brief; as well as exploring the different types of objects they were able to work with. The sample transcript below illustrates the occurrence of this event in the first 24 seconds of the tangible design session.

P1: [00:00:02] So I guess it's worked from like… like a level one? [Inaudible-5] So you're like pretty much -- [6.6]

P2: [00:00:09] Well let's just make it the whole thing. So, one puzzle that requires two moves approach-- [5.6]

P1: [00:00:15] Cool -- [0.4]

P2: [00:00:15] Another the requires three moves and anything after that. All right, so at lease, we need at least two. So, one puzzle that requires two moves and actions, let see what do we got. [9.1].

In contrast, designers in the computer-based session started by immediately identifying what objects that are available to them by going directly to the library, without any deviation or significant engagement with other members of the group. The example transcript below further exposes this observation in the computer-based design session.

P1: [00:00:01] So you've got a whole bunch of primitives, what I'll do is I'll just drag them in to space so we can have a look at what they all look like. [4.9]

P2: [00:00:05] Yeah, control D'em, yeah, yeah that sounds good. [4.0]

P1: [00:00:10] So it looks like that was a crate [pause]. This is an arrow sign... A barrel. What I'll do is that I'll centre in on these objects as well make 'em a bit bigger. Umm... barrel... We go a bomb... Umm... We got a bouncy blob. A crate... [15.2].

This initial finding suggests that tangible designers are more inclined to reformulate the design problem by suggesting new goals or ideas.

Furthermore, the study indicated major differences regarding communication within the design sessions. The designers in the tangible session communicated new goals and ideas more often than those in the computer-based session. They also communicated these ideas and goals by using action-based hand gestures and demonstrated these ideas by moving objects around whilst communicating to the rest group. See figure 8. Whereas participants designing within the computer based system were more inclined to verbally describe new ideas or goals. This was concurrence during or before a single designer moves the objects around virtually as seen below in figure 9. Additionally, the tangible group collaborated with each other more frequently and as a result, ideas were tried and tested through a rapid prototyping process (see figure 10). These findings suggest that by using action-based hand gestures and by physically moving objects around, the designers using the tangible system were more able to potentially offload cognitive function. The implication of this is that members of this group have opportunity and were afforded the ability to have a deeper understanding of the design problem.

Figure 8. Tangible Designers Demonstrating Action-Based Hand Gesture- 13:55

Figure 9. Computer-Based Designers Discussing Ideas- 9:42

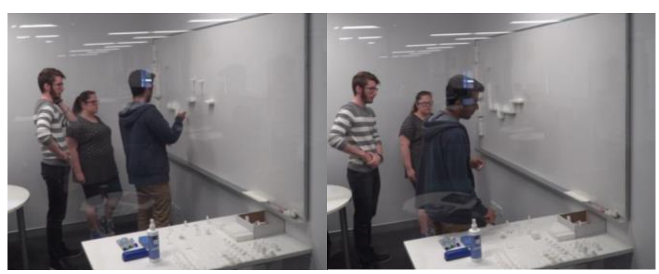

Figure 10. Tangible Designers Demonstrating Rapid Prototyping. Image Left- 5:24, Image Right- 9:24

Conclusion

This study aims to provide empirical evidence of the implications that tangible, tactile 3D printed game assets have on the craft of designing video games. It looked at additive 3D printing and how the process could be implemented into the game development pipeline. As well as the types of behaviours that come about when designing physically. This was achieved through the development of a pipeline for 3D printing for video game design and the observation of two design sessions.

The enquiry into the understanding of 3D printings position in the video game development pipeline revealed potential in the technology. While additive 3D printing still needs work to mature as a more reliable consumer product, investment in the technology could lead to a deeper understanding towards design problems. Currently, the process of additive 3D printing is not yet guaranteed, and careful and further planning is required to 3D print small and detailed models. However, the incorporation of 3D printing into the game development pipeline helped to articulate game design thoughts into perceivable concepts. This investigation revealed that by adopting a more tangible approach to game design, advantageous behaviours are more likely to develop. These behaviours encourage designers to express, explore and prototype ideas more clearly in the earlier stages of development which can result in a better-realised outcome.

In conclusion, these findings have provided empirical evidence for the following assessment: The methodology of a tangible approach to conceptualising game design thoughts using 3D printed assets can be used as an effective method to enhance the game development process.

Acknowledgements

This research was supported by principle supervisor, Mr Justin Carter and associate supervisor, Dr Ross McLennan, to whom I give thanks for their help in guiding this study. I thank my colleagues from the University of Canberra, who offered their insight, expertise and assistance to help guide this study, although they may not agree with all the interpretations and or conclusion of this paper.

I would also like to show appreciation to the participants involved in this study; as well as all others who have helped improve the outcome of this research.

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Performance Capture: Split between the Fictitious and Physical World

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Abstract
Performance Capture (PCap) is the process of capturing a continuous recording of an actor's movements and emotions using motion capture technology, typically in a 3D virtual world. This presents a somewhat unique situation for the actor in that they are challenged to imagine their virtual counterparts and a completely abstract, computer-generated world whilst delivering their performance. Central to this paper is the identification of the various implications that affect the actor's abilities during a performance by investigating professionals' experiences when using performance capture and through the exploration of the implications of performance capture in the creation of a short experimental animation.

Keywords
Motion Capture; Performance Capture; Virtual Production; Virtual World; Acting; Performance; Immersion.

Introduction
Contemporary approaches to Performance Capture (PCap) restrict the actor's perceivable world in which they are crafting their performance. Unlike a typical film shoot in which the actor is present on a physical set, PCap disconnects the physical and virtual sets and requires the actor to imagine the world around them. The research findings presented in this paper are the result of a short experimental animation that aimed to identify and resolve some of the issues of the unnatural performance environment. This study is predicated on the understanding that while there can be correlations between the virtual and the physical world, there is limited reference for the actor during their performance. This limited reference means the actor is required to memorize and imagine a completely fictitious world and still perform the standard actions of an actor.

The ability to act in a virtual world is achieved through the use of Motion Capture (MoCap) technology. MoCap is the process of measuring an object's position and orientation in physical space over time. This captured data can then be used to reconstruct the physical object's motion in a virtual space on a computer. Motion capture has been widely used to record human motion by tracking various parts of the body in relation to one another and mapping that motion to a virtual character in the computer, which is typically represented visually as a three-dimensional computer model [1]. An example of this process can be seen in Figure 1. MoCap is the foundation technology that enables PCap and, although this technique still uses MoCap technology, PCap is aimed at capturing a continuous performance, including an actor's movements and expressions as opposed to isolated actions. PCap is an emerging field of practice and has been adopted by both the film and game industries because of its ability to map an actor's performance to a virtual character, otherwise known as an avatar [2] [3].

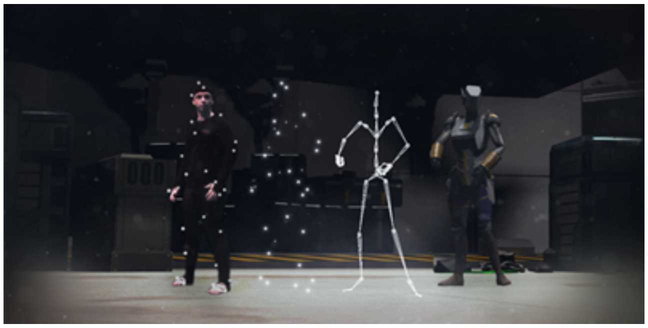

Figure 1: MoCap virtual relationship process

PCap is closely linked to a new production technique called virtual production. This technique introduces virtual camera systems (VCS) that allow CGI and visual effects to be experienced in a similar manner to a live-action production. By combining PCap and the VCS it enables the creative flexibility to manipulate virtual objects as if they are physical [4] [5].

Contextual Review
Continued technological advances place PCap in a constant state of flux as new forms of motion capture and virtual production tools continue to be developed. This is significant because it prompts each new production to push the technique into creative boundaries that have yet to be clearly defined. For example, digital visual effects studio, Weta Digital, pushed the boundaries of PCap for the films *Rise of the Planet of the Apes* [6] and *Dawn of the Planet of the Apes* [7]. In these films, Weta Digital explored new techniques in PCap by taking the performance out of the empty studio and into a physical location as seen in Figure 2.

Figure 2: Weta Digital PCap in a physical location

This approach to capturing the performance on location allowed for the physical interaction with the environment and, therefore, allowed actors to deliver a more believable experience to the audience. As Barbara Flueckiger explains, a tangible interaction between the physical and virtual elements of CGI is one of the major problems confronting the believability of the illusion [8]. For Weta Digital, this believability was achieved by the virtual character's ability to touch physical objects or people in the scene, which created a more organic presence and behavior that is more organic compared with working in the studio [9].

In an interview with Fresh Air's Andy Serkis, he describes the impact of bringing PCap out of the studio:

"The process of performance capture really is transparent now. You know, we're not having to shoot in special areas where the performance capture cameras are all around. Those performance cameras are brought out into the open, outside of the studio lot, you know, and you can shoot on any location. And while they're rolling, while the performance capture cameras are rolling, the live cameras are also rolling, and so everything is filmed in one hit, that enables you to completely emotionally connect with your fellow actors and completely allows play with the scene in entirety, and it will have an emotional resonance and a reality and a connectiveness that you couldn't possibly get if two actors were working in separate volumes" [10]

This approach has successfully removed the need to memorize the environment, which alleviates the strain on the actor's imagination and allows the actors to focus purely on their performance. This approach is not a valid solution to every production that uses PCap, because not every production is based in the realm of realism. The alien planet Pandora, in the film *'Avatar'* [11], is a prime example of an environment that would be difficult and costly to recreate as a physical location for a production. Productions that are based on completely fictitious worlds require the development of virtual worlds to deliver the end product. This means that they can be used as a reference throughout the production.

Common acting methods are still applicable in PCap because it is still performance-based—an example of these methods is Stanislavski's System [12]. When considering Stanislavski's System in relation to PCap there are many correlations that could help an actor deliver their performance. However, some of these techniques are more significant than others when comparing them between acting in the virtual world and acting in live-action productions. For example, the requirement for an actor's imagination in PCap is considerably larger than on a live action set or stage.

This emphasis on imagination is due to the contemporary acting environment of the virtual world. Currently, PCap does not provide a natural performance environment for an actor because the virtual world is neither visible nor perceivable. In a live-action or stage production an actor would be placed in a real-world environment and be surrounded by physical objects as well as other physical actors in appropriate costumes. Even the surrounding conditions like environmental sounds, smoke, and rain can be created or simulated, which feeds the actor's performance. However, when considering a completely fictitious world, all these elements are computer-constructed and to deliver their performance an actor needs to memorize the location, size, shape, and trajectory of objects, including other virtual characters in the virtual world [13].

Currently these elements can be visualized in real-time on the VCS or on screen-based technology like televisions or projectors. This approach enables the actor and director to view the virtual world on set. This viewable virtual world is only used as a reference. During a performance any screen-based technology with the viewable virtual world can lead to the actor's attention being split between the fictitious and the physical environments, which can negatively impact the believability of their performance.

For the purposes of this paper, a believability in a performance is the actors ability to create an illusion of life in the virtual character, which facilitates a suspension of disbelief in the audience [14] [15]. PCap is focused on the actor's performance so they can deliver a believable virtual character to the audience. However, the current approach to PCap burdens the actor with creating and maintaining a fictitious world which can impact their focus on the performance and, in turn, believability may be lost.

Research Problem

As previously mentioned, one of the major issues with PCap is that it does not provide a natural performance environment for an actor, especially when compared with stage or film acting. This is because the virtual world is an abstract computer construction that the actor cannot naturally see, hear, or touch in the way they can with a physical set. To deliver their performance, an actor needs to memorize a large amount of information about the virtual world that is not normally required by other modes of performance.

A prime example of the difficulties of PCap was given by Valorie Curry when describing her performance in the short real-time animation *Kara* by Quantic Dream [16]. Valorie identified the exact difficulties of working in a virtual world and how she had to imagine and interact with a completely fictitious world and still perform the standard tasks of an actor. Furthermore, in the behind-the-scenes of *The Hobbit: The Desolation of Smaug*, Benedict Cumberpatch further establishes this issue by speaking about the intrusiveness of a MoCap facial camera and imagination requirements of the actor during PCap sessions and, more specifically, the sense of grandeur when performing as the Dragon, Smaug:

"This camera is really weird cause its right in your face, it's got to a little circle of LED lights so you're literally carrying

around the actress's dream, you have your own little private keynote. It's really nice but actually its very, very weird and then you kinda have to forget it and imagine yourself into a vast creature that is in a huge space when you're really crawling around on a grey bit of carpet…" [17]

Whilst Benedict's performance was directly translated to Smaug, his choices affected the end performance and his comments on the performance environment directly relate to the issue with PCap.

Experiencing the Problem in a Short Production

To further establish this issue, I conducted research by performing in a short experimental animation named *Powers Above.* By taking this approach, I could experience the effects of acting between the fictitious and physical worlds of a short experimental animation. During the early stages of development, a sci-fi world with two virtual characters was created with attributes that were required to fully experience the issue as seen in Figure 3. The first virtual character was a female enforcer and was developed with standard human anatomy; however, the second virtual character was based on a troll, which is vastly different from the human anatomy of the enforcer by having elongated arms and a wide menacing body. These characters allowed me to experience the difference between a character that is inherently familiar and a character that is unfamiliar in relation to physical form and movement.

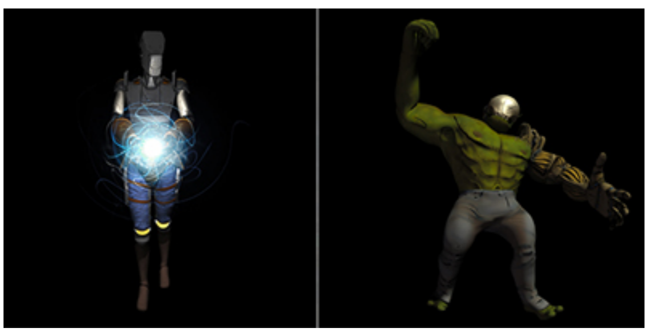

Figure 3: Virtual characters used in Powers Above

During the performance of each scene, I took the role of each virtual character, acting to scenes in order of the script and conducting multiple takes to meet the needs of the director. Each scene started with practices and guidance from the director, where I was able to see the viewable virtual world that was projected onto a wall. Being able to see the virtual world allowed me to develop an understanding of my relationship with the world and the characters within it. This was a vital step in the process of my performance because I developed a relationship with a virtual counterpart and understood how my movements translated to the virtual world. This approach to viewing the virtual world before a performance is commonly adopted by the industry. In an interview with Andy Serkis on the *Adventures of Tintin: The Secret of the Unicorn* [18], he talked about how viewing the virtual world enables him to develop a virtual reality through his imagination:

"…You can actually see the environment virtually. You're looking, as the director does, looking into a monitor. On stage there will be a bunch of wire frame representations of the set, but actually when you look into the monitor I can see Captain Haddock and Tintin, so your mind begins to work that out and your sort of mental GPS kind of creates this virtual reality and real world that you inhabit…" [20]

This relationship with the virtual meant I could identify whether my movements seemed believable when applied to the virtual character. It was easy to achieve a believable performance as the enforcer because I could easily replicate her personality by making my movement stiff and confident to represent someone that had formal training as seen in Figure 4. Achieving a believable performance for the troll was harder due to the virtual character size and weight. The Troll in relation to me was taller, wider, and heavier, which made any movement hard to achieve. This meant my focus was required heavily for the physicality of my movements and the performance and any ability to imagine the world around me was lost which affected the believability of my performance when moving around the world.

Figure 4: Enforcer PCap comparison

Multiple practice takes were conducted until I felt confident that I could perform without the aid of viewing the virtual world. It was important to develop a strong understanding of the virtual world because any reference to it during the recorded takes would split my attention split between the fictitious and the physical environments. This split of attention only occurred when I saw the virtual representation of my performance during my performance which created doubts in my performance decisions and pulled my attention to the screen of the viewable virtual world. By removing all references to the virtual world I could focus my attention on my performance and the director's notes during the recorded takes. Similar to the practice takes, multiple takes were conducted until the director was happy with the recorded performance.

When it came to simple scenes that had limited movement and performance, there were no major issues with achieving the performance in a small number of takes; however, complex scenes that had multiple queues, movements, and emotions were difficult to achieve because there was more information that needed to be remembered and retained. These complex scenes split my concentration on the requirements of the scene, the virtual world, and my performance, which led to more time being spent on achieving the required performance. In some circumstances, the director gave verbal queues to alleviate the need to remember some of the information required for the scene and this improved my overall performance.

A common issue that was encountered when performing in the virtual world was the penetration of virtual assets. This meant that I could walk through walls or boxes that were in the scene, and further direction and takes were required to overcome this penetration. Sometimes penetration was unavoidable and it would be fixed in post-production; however, at other times physical props where introduced to represent an asset in the virtual world like a box or wall.

The final factor that impacted my performance was fatigue. With each take I became less focused and more disgruntled even with short breaks and hydration. An overall period of two hours was spent until this gradual effect took hold and caused major issues for my performance. Once this point was reached, it was extremely difficult to achieve the performance required for a scene so a large break was taken to refresh and relax.

The outcome of the research test reinforced the comments made by the professional actors and showed that the large amount of information required to perform in a virtual world can affect an actor's performance. Whilst this issue is prominent with PCap, there are ways to resolve the issue and new ways evolving with advances in technology.

Resolving the Problem

The current approach for resolving the issue in PCap is exposure to these unnatural performance environments. With time and practice, performing in a virtual world becomes more intuitive. Ultimately, this means the actor learns how to retain the information and perform as though they're on a live-action set. Whilst this approach is successful, it requires time and a significant amount of experience with PCap to achieve. Andy Serkis speaks about the difficulties faced by other actors in an interview on his captured performance in the *Adventures of Tintin: The Secret of the Unicorn* [18]:

"…That's just part of the craft, I suppose, learning how to use it. Some actors do find it, when they first do it, they feel very naked because they're used to having props, they're used to having costume, they're used to having makeup, they're used to having shoes to make the character feel a certain way. That's an important part of the acting process, to choose your costume; you don't have that with this so you have to do it in other ways. You have to mentally construct those things and actually find different routes. As I say, this is, for any actor, a huge challenge in creating inner life for something and knowing how you relate to- how your performance calibrates to an avatar. It is like mask work or puppeteering, being both marionette and puppeteer. You're imbuing the character with life and there's a sort of- in some ways its no different at all, and in other ways there's a kind of third eye on your performance, an awareness of what it is that you're doing with your avatar…" [20]

This notion of the actor mentally constructing their surroundings and finding different routes to calibrate themselves with their virtual counterpart, is a testament to the experience Andy Serkis brings to PCap. However, Andy's comments highlights that he is embracing the identified issue of the unnatural performance environment.

Instead of embracing the problem, new approaches need to be identified to overcome the unnatural performance environment and bring it closer to an environment typically found on a live-action production. The VCS is a prime example of a technology already resolving the disconnect between the real world and the virtual. The VCS is specifically designed to mimic a typical camera from a live action production while simultaneously allowing the director to see the virtual world in real-time.

A similar approach that looks to resolve the disconnect between the real world and the virtual world can be considered for actors. The current process of PCap links an actor's motion captured performance with a virtual world. Additionally, this process provides all the elements required to create a new reality in which an actor can perform. The only element missing is a device that can immerse the actor in their virtual world, replacing the physical world with the virtual.

Virtual Reality (VR) or Augmented Reality (AR) headsets are immersive technologies that could provide a view for the actor into the virtual world in real-time. VR headsets enables the simulation of a new reality creating an immersive experience of a virtual world [21]. Additionally, with the use of motion capture the actor could even interact with virtual world. On the other hand, AR supplements the real world with the virtual by creating an environment for 3D assets to be layered on top of real world [22]. Whilst this approach could remove the unnatural performance environment, further research would be required to establish its viability.

Conclusion

In conclusion, this paper has identified the unnatural performance environment of PCap for actors and how it limits their performance capabilities. This ongoing problem with PCap has been indirectly identified by industry professionals and needs to be addressed. The short experimental animation *Powers Above* explored the issue which identified implications that affected the believability of an actor's performance in a virtual production.

Furthermore, VR and AR technologies should be explored as viable solution to the problem of an unnatural performance environment for actors, by establishing an immersive virtual experience. This process could be adapted into PCap to improve the perceptual awareness of the actor, better enabling their engagement within the virtual world as they perform.

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Early Development of a Flexible Procedural Approach to Automatic Jazz Improvisation

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Abstract

This paper describes early work on an approach to automatic improvisation in the jazz idiom, derived from analysis of human practice, with algorithm development in the Jython Environment for Music (JEM). From the outset this project sought to be inspired by the human process of jazz improvisation and to apply as directly as possible the logic and processes of a human engaged in the activity of jazz improvisation – without necessarily using any specific computing technique or algorithm class. This paper describes the thinking and early experimentation leading to the current prototype version which improvises essentially in real-time and demonstrates how the use of variable parameters can greatly increase the flexibility of procedural programming.

Keywords

Automatic jazz improvisation, generative algorithm, artificial creativity, algorithmic music

Introduction

Development of melody-generating computer algorithms has tended to track trends in computer science over the past 60 years. A quick survey reveals 'hard coded' (and in some cases 'hard-wired') computational procedures that were used in the 1950's and 60's when computers were little more than calculators, followed by a move toward libraries of musical snippets for recombination, exemplified and arguably reaching its zenith in David Cope's *Experiments in Musical Intelligence* [1]. The past two decades have seen an explosion of techniques including evolutionary algorithms as typified in the work of Biles [2], exploration of Markov Models as seen in some of the work of Pachet [3], development of grammars, notably by Keller [4], and the application of machine learning concepts as seen in works such as Gillick [5], including some quite promising developments with deep recurrent neural networks such as the work of Colombo et. al. [6].

Part of the problem of developing an algorithm for the generation of jazz solos is the need to observe the conventions of the idiom. This in itself is not necessarily difficult; one merely needs to identify the specific conventions to be observed and then write procedures based on those conventions. Self-evidently, such a 'hard coding' approach might produce acceptable jazz solos but those solos would tend to be very conventional and are likely to sound the same or similar every time.

The converse part of the problem, then, is the need to produce variety and novelty. Again, this in itself is not necessarily difficult; simple randomisations and probability weightings have been used for this very purpose for decades and are still a key part of many techniques in use today. However, while randomisation can be useful for breaking down an otherwise repetitive structure, in the absence of suitable constraints it tends not to be useful for creating within an established idiom. Randomisation is, unsurprisingly, too random.

One technique that has been used to address this balance with considerable success is *recombination* of pre-defined musical snippets. This was the core mechanic behind David Cope's *Experiments in Musical Intelligence* [1] and today is the core mechanic behind a well-known and commercially successful software package that produces solos over the user's chord progression in a variety of styles. Recombination works because snippets characterising the desired idiom can be selected while the recombination mechanism allows for many different solos to be generated from relatively few snippets (and, in some algorithms, transformations of the snippets). Thus the need for variety and novelty is addressed while remaining within the conventions of the target idiom.

A human jazz improvisor possesses the ability to generate sequences of notes that he or she has not heard or practised before, irrespective of whether that ability is called upon frequently, rarely, or not at all. This ability to create – to generate – is inherently missing from an algorithm whose core mechanic is recombination. For this project, it was determined that the core mechanic should be fundamentally generative rather than recombinatory.

The core challenge was to achieve variety and novelty within the convention of the jazz idiom, while also being genuinely generative. Of course this nature of challenge is not new. All contemporary generative algorithms, viewed through the lens of variety/novelty and conventionality, can be seen to address it one way or another. For example, a Markov Model approach can have its weightings adjusted to balance the proportion of conventional to unconventional choices. A Grammatical approach can use an alphabet that provides a variety of more and less conventional outcomes and in the case of a probabilistic grammar the weightings can be adjusted to taste. When it comes to evolutionary algorithms and machine learning techniques the workings are obfuscated and there may not be any discrete lever to pull; nevertheless, any given implementation will, in its totality, result in a certain balance of variety and novelty against conventionality.

Early Work

The Jython Environment for Music (JEM) was selected as a suitable programming environment to start work. Aside from being open source free software and portable across the major operating systems, JEM offered numerous useful music-specific functions and abstractions including built-in MIDI functions. The use of the Python programming language was considered an advantage, as was the existence of a comprehensive text [7].

Exploration

Early work consisted of testing and becoming familiar with the environment by writing a progressive series of lightweight music generation algorithms as explorations without any specific goal or strategy. The results of those early tests were recorded with a *Band in a Box* backing and published on YouTube at https://www.youtube.com/channel/UCGTlKqu5PkC1CRh0mL5bTdA . The solos were output as MIDI files, which are notated below.

The first experiment simply read a chord chart and played the root note on the first and third beat of each bar. The following output is from the *A-section* of 'Autumn Leaves':

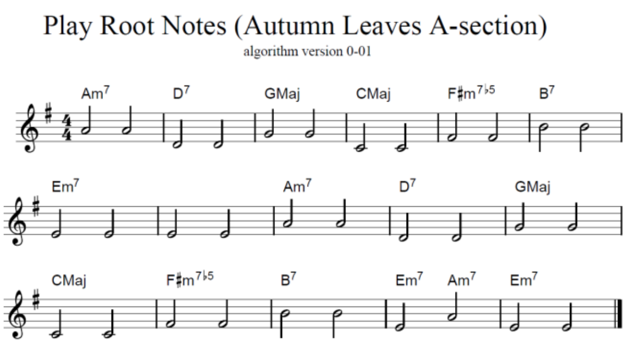

Figure 1. Example output of version 0-01

The second experiment was a development of the algorithm to play the nearest chord note:

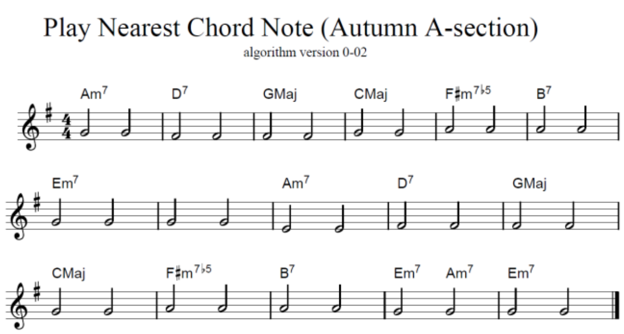

Figure 2. Example output of version 0-02

The third experiment attempted to introduce rhythm. A single, set rhythm was selected from the list of *Jazz Rhythms* in the *Red Book* [8]. The algorithm was developed to select stochastically from six pre-set melodic shapes (rising, falling, rising and then falling, falling and then rising, rising then falling then rising again, and falling then rising then falling again), as well as an overall qualitative range for each phrase (small, corresponding to a few tones; medium, corresponding to about half an octave; or large, corresponding to about an octave). Each resulting phrase shape and range was then mapped to the chord and scale notes appropriate to the chord changes. For simplicity, only four scales were used (Ioninan, Dorian, Mixolydian, and Dorian with flattened 5th and 9th)

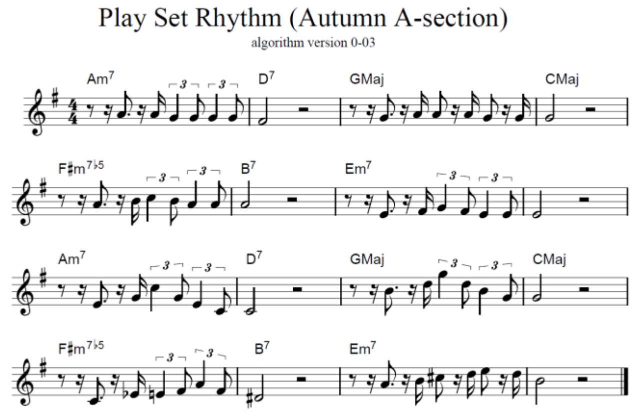

Figure 3. Example output of version 0-03

Even though this approach produced subtly different melodic lines from one phrase to the next, the repetitive nature of the rhythm was quickly found to be aesthetically unpleasing. This led to version 0-04 in which all six of the *Jazz Rhythms* in the *Red Book* [8] were programmed into the algorithm for stochastic selection. Melodic shape followed the same approach as version 0-03. The example solo covers once through the whole of Autumn Leaves.

Figure 4. Example output of version 0-04

The interested reader can find archived versions of these early exploratory algorithms on Github at https://github.com/Dan-field/Jazz/tree/DevArchive

More Flexibility Required

Although interesting and promising to an extent, it was recognised that these test algorithms would not be suitable for further development. By version 0-04 the algorithm had grown to over 300 lines of Python code with internal complexities that were imposing constraints on the algorithm's flexibility. Simply adding more rhythms and melodic shapes would only take the algorithm so far. Essentially, what had been produced was a hard-coded algorithm that would sound similar every time. A fundamental rethink was required, along with a more modular approach that would allow sections of the algorithm to be changed without affecting other parts.

Developing a Model

Inspiration from the Human Improvisor

The project was initially proposed to use rudimentary jazz study literature and beginner-level improvisation lessons as material to model the sequence and thinking of jazz improvisation by a student. The reasoning was that the teaching of jazz improvisation had been refined over many decades and could therefore be considered an optimised algorithm in its own right. Examples of references include Jamey Aebersold's *Jazz handbook* [8] which is probably the most widely circulated of all jazz texts thanks to being provided free of charge for over 40 years with regular updates. Additionally, a quick survey of available jazz study literature identified some that include extensive procedural instructions which may lend themselves to coding as a computer algorithm. The stand-out example of this was Shelton Berg's *Goal-Note Method* [9] which in some sections literally lists step-by-step instructions on the process of constructing a solo line. In all of this, the intent was to focus on the process that the human follows, rather than specifically implementing any one particular computer science technique.

This initial aim had to be refined as much of the early work – in particular, text reading and reflective practice – revealed a significant amount of interpretation and assimilation on the part of the improvising jazz student. The texts and notes given to the students are not comprehensive descriptions of what to do; rather, they guide and prompt the developing student's practice-based learning. Even the most algorithmic of texts left a lot to the judgment and practice of the musician; albeit not as much as other texts. With this realisation, the focus of the modelling necessarily shifted away from absolute reliance on the texts and lessons, toward a desire to understand and model the total improvisation practice involving person + processes + instrument.

An essential and realisable model

A model of the human jazz musician was developed over time through an iterative process involving reading of jazz texts and notes, reflective practice and peer discussions.

The model was intended to be *essential* insofar as it must cover the core processes and activities happening at the moment of, and contributing to, the generation of the jazz solo, and no more.

It was intended to be *realisable* insofar as it was developed with the end-goal of an algorithm in mind. It was recognised that some of the core human processes – such as emotion – are not realisable as an algorithm (or, in any case, an attempt at realisation would constitute a lifetime's study on its own and therefore lies outside of the scope of this improvisation algorithm). Such processes would need to be represented by simplified proxies in order to maintain realisability. Many of the considerations relating to realisability were informed by the exploratory work described above.

The model that started to emerge through this iterative process viewed the jazz improvisor as a person who possesses knowledge of certain rules. "Rules" used here in a broad sense to include the theoretical (such as jazz harmony), the practical (such as playing in time), and the intrinsic rules that a human musician takes for granted but a machine does not – such as the imperative to play anything at all (a few notable exceptions aside). The jazz-improvising person may or may not choose to follow the rules at any given moment – indeed may frequently make the artistic choice to break the rules. But, at least in traditional and mainstream jazz, they must possess knowledge of the rules in order to be considered a jazz musician.

As the model was further developed with an eye on being algorithmically realisable, it was determined that most of what's going on during improvisation can be classified as either a *process* or a *choice*.

- **Processes** may be analytical or practical.

  Analytical processes are generally defined in texts and may be executed by the human musician in advance of actual soloing. Examples include the identification of key including any modulations, recognition of familiar or standard chord sequences, analysis of modes, and identification of harmonically important chord notes.

  Practical processes are not always identified in jazz texts. Some were identified through reflective practice and peer discussions. Examples include performing the mechanical processes or gestures involved in playing, keeping in time, and keeping track of progress through the lead sheet or chord progression.

- **Choices** are made in a variety of timeframes and affect such artistic outcomes as style, feel, novelty and aesthetic. It is understood that these choices may be the result of many factors from the arcane (musician's intent, mood and emotion), to the prosaic (musician's practice habits, established patterns, and limitations).

  Certain choices are unavoidable if there is to be a solo. For example: the choice to play a note vs rest; choice of pitch, duration and rhythm.

  Other choices affect the artistic outcome without being fundamentally essential. Examples include: choosing more bluesy vs more 'straight' notes, steady vs highly variable rhythms, playing within the typical modes vs playing 'outside', developing a theme through an improvisation vs a more variable/random choice, and the 'tightness' or 'looseness' of swing triplets.

Toward Realisation

Armed with this still-developing model and the lessons learned from the exploratory work, the next step was to begin development of a model-based algorithm. A decision was made very early to develop the algorithm incrementally. Each increment would be runnable and testable. This approach would allow ideas to be tested and issues to be ironed out iteratively. It was also decided that the algorithm should be written, so far as could reasonably be achieved, in a modular fashion.

Deciding on an Algorithm Class

It was noted that the model's analytical and practical processes lend themselves to a 'hard-coded' approach. Such processes as key identification and mode analysis are, for the most part, rule-based activities that the jazz student learns from a textbook. Such rules can be coded into a computer.

In contrast, the human choices in the model are not suited to hard-coding; that would make the choices too rigid and the output stylistically narrow. Instead the choices tend to suggest more flexible techniques such as a probabilistic approach (Markov models, grammars) or machine learning.

AI for everything?

The possibility of using a machine learning technique such as a neural network was carefully considered and ultimately rejected primarily because of the project's "direct" ethos together with concerns about control over the outcome, acceptable levels of technical difficulty, and the nature of the project.

The intent is to apply as directly as possible the logic and processes of a human engaged in jazz improvisation. A machine learning technique would need to be provided with training data (in the form of example solos) from which it could develop its own internal model of the logic and processes. A quick literature review revealed that the reasonably successful neural network approaches required thousands of examples in the training set. For example, Colombo et. al. [6] used a corpus of 2,158 Irish melodies in order to train a deep recursive neural network to compose music in the style of an Irish melody (noting that, stylistically, the *Irish melody* idiom is narrower than the jazz idiom). If such an approach were to be taken, the project work would consist almost entirely of obtaining (or creating) the required examples and converting them into a form that's useful for training. Once all of that is done and the neural network is trained, the resulting AI would simply "work how it works", in the style of its training and without flexibility. The neural network's inner workings would be obfuscated and inaccessible. There would be no way to tweak or adjust the results, other than modifying the training data set and trying again. Neither the development process nor the probable outcome would satisfy the aim and intent of this project.

What about more advanced AI techniques? A quick survey of AI-related journals (for example, the publications of the IEEE Computational intelligence Society) provides some insight into the tremendous amount of research currently going into the development and refinement of AI techniques and their application across many disciplines including artificial creativity. Again it was the project aim that guided the decision: this project was to be fundamentally a musical project. The application of computer science was only to be made in the service of the musical goals, never as an objective in itself. An attempt to implement any specific advanced AI technique would fundamentally change the nature of the project away from music, toward AI research.

With all of these considerations, it was determined that AI would be used only where it brings a pragmatic benefit.

Improvising in Real-Time

The initial test algorithms were written to generate complete solos as MIDI files that could then be played back. After reflection on the project aim it was determined that the algorithm should work in real-time or near real-time because this more closely matched a human improvisor. In order to realise this, a core "player" function was developed. At its most minimal, the player is a piece of software that waits for the next beat and then plays the next note. It works in tandem with a timer function that sends out 'taps' at the required tempo. The note or notes for the next beat are planned while playing the note/s of the current beat.

And so the core of the algorithm was defined.

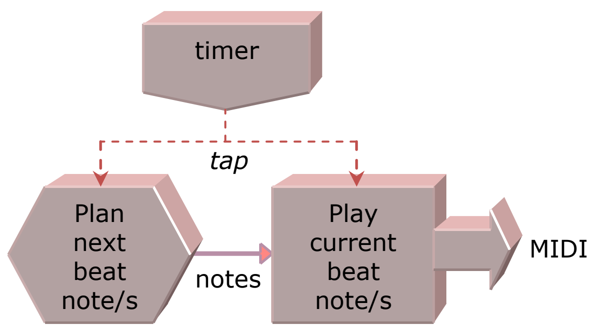

Figure 5. core of the algorithm

This (near) real-time core was introduced in version 0.05 of the algorithm and was further refined in version 0.06.

Achieving Flexibility with Parameters

In beginning to hard-code the basic rules of jazz soloing for version 0.07, it was observed that numerous choices and judgment calls were required. These choices were integral to the coding of the algorithm. For example:

- When soloing on the major root chord, which mode should be favoured? Ionian (traditional) or Lydian (contemporary)?
- Under what circumstances should an altered scale be used? Always on any dominant? Always on a secondary dominant? Never?
- When should the blues scale be favoured?

There were also numerous decisions of a more mechanical nature. For example:

- How to decide whether the next note should be higher or lower than the current note,
- How to decide how much higher or lower,

It was estimated that dozens – and potentially hundreds – of such decisions would need to be made by the time the algorithm was complete in a future version. With each choice the algorithm was being tuned to behave a certain way; to become stylistically narrower. There was an awareness that this would lead to a less flexible and more predictable algorithm.

Flexibility as a Necessity

Alongside the development of the algorithm, some directed reading reinforced the need for flexibility in the algorithm. Huron [10] discusses the psychology of expectation as it pertains to music. In so doing he enumerates some algorithmically useful measures of melodic movement such as step declination, step inertia and melodic arch. In a different but comparable vein, Temperley [11] catalogued well-formedness definitions and preference rules pertaining to six aspects of musical structure covering meter, phrase, counterpoint, melody, harmony and key. The possibility of hard-coding these definitions, rules and measures was considered; doing so would constrain the algorithm to produce only solos that are well-formed and that conform to expectations. However, it was once again a consideration of the project aims that highlighted the undesirability of excessive hard-coding: a human improvisor is able to improvise melodies that may or may not satisfy Temperley's definitions of well-formedness, and he or she is able to conform to expectations as well as to surprise with something unexpected. Through such considerations, it became self-evident that the algorithm would necessarily require enough flexibility to play it either way.

Parameterisation of a Choice

Being wary of the undesirability of a less flexible and more predictable outcome, a decision was made to experiment by turning one of these choices into a variable. At the time, a part of the algorithm was being written with a *target step size* which would strongly affect the size of the melodic interval to the next note from the current note. Recognising that hard-coding a target step size would remove a great deal of flexibility from the algorithm, it was instead coded as a variable that could be set through a user interface in the form of a slider. And just like that, the algorithm became interactive.

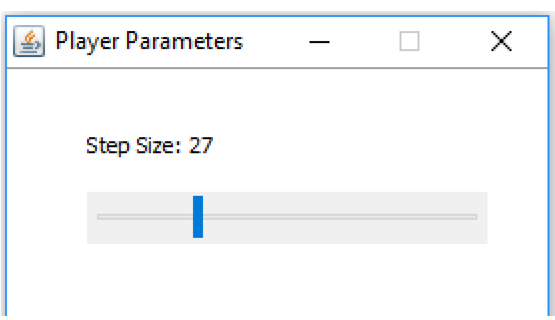

Figure 6. slider used to control the 'target step size' parameter.

Experimentation with the slider was quite satisfying. Here was an algorithm that was generating a rudimentary jazz solo (albeit just a stream of eighths with no phrasing) and responding almost immediately to any changes made to the slider. The value was set in tenths of a semitone with a range from zero to 100. Low values around 20 to 30 (that is, 2 to 3 semitones) tended to produce noodling ditties while larger values around 60 or higher tended to cause the solo to jump all over the instrument's range. Of particular interest was the effect created by varying the slider intentionally mid-solo. One approach was to hold the value around 20 to 30 for a while, then change to a higher value for a few beats before returning to a low value. The result was a solo with greater variety than could be achieved with any static setting. And with a human input that could be used to inject genuine human intent. A video of this in action is on YouTube at https://youtu.be/TM8eOUlHc6M .

A Hybrid Approach Emerges

The experience with the slider led to thinking about a hybrid programming approach where the 'rules' are detailed using procedural programming (this is something that procedural programming is well suited to), while the choices and responses to the rules could be managed by means of variable parameters which affect the workings of the procedures.

Control (Proposed)

Those variable parameters provide a number of opportunities for control.

1. **Human controller**

   A human could have a computer or a custom-made control device that allows manipulation of the control parameters. Parameters could be combined or selected to limit the number of controls to a reasonable number such as 10 to 15.

   This concept has the potential to be developed into a human/machine collaborative musical instrument in its own right.

2. **Automatic control using parametric paths**

   The control variables provide a multi-dimensional parametric space. Each location in the parametric space produces a somewhat different jazz solo from adjacent locations. Paths through the parametric space could be planned and pre-set, or randomly generated, to achieve solos that develop in some way.

3. **AI control**

   The problem of training a machine learning algorithm could potentially be simplified if the training could refer to control parameters rather than sequences of notes. This somewhat abstracted approach may significantly reduce the overhead on the machine learning algorithm by eliminating the need for it to self-organise its own harmonic rules (since these rules are handled by the underlying procedural programs). This would in turn allow for a smaller-dimensioned or simpler AI, which in turn allows the training set to be smaller without risk of overfitting. If applied carefully and skilfully, this approach may allow an AI to be trained using only a few hundred exemplary jazz solos, without the need to fill out the training set with thousands or millions of 'mediocre' examples.

   The proposed AI approach is out of scope of the current project; it is mentioned for completeness.

An Overview of the Current Prototype

At the time of writing, the algorithm is at version 0.07. This version first introduced and tested the viability of control parameters using just one variable parameter; target step size. It is the version that was used in the YouTube video. The source code (for use with JEM) is available at https://github.com/dan-field/jazz/tree/v0-07_record

Figure 7 illustrates the working of version 0.07.

The core of the algorithm is the *player*. Its job is to play the current beat while preparing for the next beat. It receives taps from a timer function which includes a tempo control slider.

Alongside the *player* is a *LeadSheet*. The LeadSheet initially reads in the chords from a text file, then sends the chords off to an *Analysis* function which tells the LeadSheet what key it thinks the chords are in. This happens before the start of the solo.

Version 0.07 always plays eighth-notes; there is no phrasing and no rhythmic variation (bearing in mind that the algorithm is being developed incrementally; future versions will introduce phrasing and rhythmic variation). This means that the task of preparing for the next beat is essentially concerned with choosing two notes. The *player* chooses two approximate target notes based on the setting of the 'Step Size' slider. If the setting is 27 then the player will make selections involving intervals of 2.7 semitones, limited to the range of the instrument. Whether these notes are higher or lower is handled probabilistically in this version (will become a variable parameter in a future version).

As well as selecting two approximate target notes, the *player* queries the *LeadSheet* about the next beat. The LeadSheet responds by telling the player what the chord will be on the next beat and what key the *Analysis* said it was in. The LeadSheet receives its own taps from the timer and uses them to keep its own place in the chord chart.

At this point the *player* has selected its approximate target notes for the next beat, and it has received information about the chord and key on the next beat. It sends the chord and key information to the *ScaleTheory* function which selects a scale or mode based on the chord/key combination. The ScaleTheory function returns the selected scale or mode to the player in the form of a list of all notes in that scale or mode. Additionally, it returns the chord notes in the form of a second list.

Of note is the fact that ScaleTheory is a module which could be changed out for an alternative harmonic module (noting that none have yet been written) if desired.

The player compares the approximate target notes to the notes in the lists that it received from *ScaleTheory*. It has been hard-coded to select the nearest chord note on a strong downbeat, and to select the nearest scale or mode note in all other cases. (Again, this hard-coding will become a variable parameter in a future version).

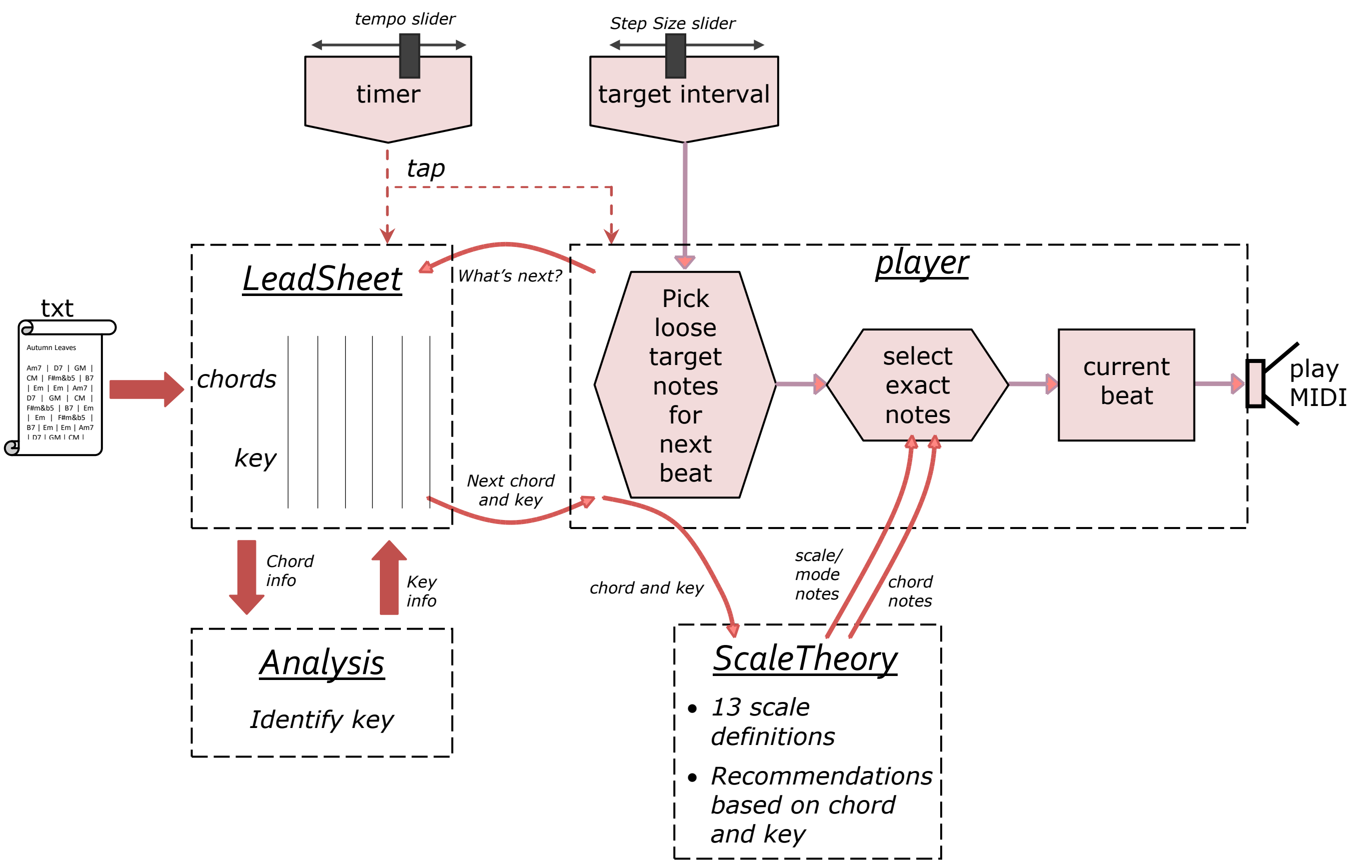

Figure 7. Workings of the current algorithm version 0.07

Now the next two notes have been selected. There is nothing more to do but wait for the next tap from the timer and start the process over again

Version 0.07 is very much an early prototype. Further work is planned on almost every aspect of the algorithm. The next significant tasks are to introduce phrasing, to introduce a mechanism for rhythmic variation, and to convert hard-coded choices into variable parameters.

Acknowledgements

I would like to acknowledge the support and thought-provoking guidance of my research supervisors, Dr. Andrew Brown and Dr. John Ferguson.

I would also like to thank the Qld Conservatorium, Griffith University, for being prepared to 'take a punt' on accepting me as a candidate and allowing me to have a red hot go at my passion project.

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Autonomous Music Composer Based on Affective Principles

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Abstract

Over the past 60 years, there has been much research into the field of algorithmic composition. Techniques have been refined, and processes developed to suit a variety of needs. Recently however, focus has been turned to algorithmic composition for more emotive purposes. Affective Algorithmic Composition (AAC), the product of this research is a rapidly developing field, with many potential applications. In particular, AAC has the potential to solve one of the most prevalent issues in game audio, that is, repetition of a soundtrack. The research described in this paper covers the implementation of an Affective Algorithmic Composition system into a computer game. The methodology used is based upon Design Science Principle. Using Lindenmayer Systems and Markov chain theory, a fully functional system was developed.

Keywords

Video Games, Markov Chains, Algorithmic Composition, Generative Music, Lindenmayer Systems

Introduction

For almost the entirety of recorded history, audio in some form or another has played a crucial role in conveying and constructing emotional and immersive experiences. From simple folk melodies at dances, to films set to orchestral masterworks, no other medium is as effective at this task as sound. It stands to reason then, that video games, being an interactive medium, would follow suit. Drawing from film and television scores, game soundtracks were initially little more than loops, set to run on repeat forever, or at least until the game ended. This was primarily due to severe limitations on the amount of space video games could allocate to the audio samples. However, as the technology surrounding both audio and game creation improved, composers and sound designers have quickly found themselves faced with a daunting array of tools and a perhaps even more daunting set of expectations from customers.

The desire to fulfil these expectations has led to the creation of elaborate scores, with parts able to be faded in and out, motifs to be triggered at will, and a great deal more besides [1,2]. However, there is still a reliance on pre-composed music. This generally leads to some degree of repetition, an issue which while acceptable in static mediums such as film, can have a drastic impact on the enjoyment of a video game, with repetition being described as "distracting, or even worse, irritating which can have a knock on effect on player immersion"[3]. Algorithmic composition is one suggested technique to remove or at least reduce this issue. Having a computer generating a soundtrack allows for an effectively infinite soundtrack, with little to no repeating if desired. Unfortunately, there is no straightforward solution. Repetition is a key part of much of the music that exists, whether through a repeating rhythm, melodic motif, or other musical structure [4]. Repetition in game soundtracks is a well-established part of the current video game industry. However, the emergence of more emotionally geared games in the independent video game sector has led to a demand for more dynamic sound tracks. Finding a method to increase the dynamic nature of soundtracks is of paramount importance. Using computers to compose the music is one proposed solution to this problem.

Following on, by reviewing literature surrounding algorithmic composition in the context of a video game, several gaps arise. What challenges can be found in the process of designing and implementing an Affective Algorithmic Composition engine into an interactive medium, and if any, how can they be best resolved. Using design methodologies and processes based upon Design Science Research Methods [5], this study addresses the lack of information in regards to successful implementations of any algorithmic compositional system that is designed to enhance the emotion, in a game. The approach detailed in this paper combines stochastic processes based on Markov chains and rule-based grammars based on Lindenmayer Systems. The outcome of this research paper is a fully generative, realtime algorithmic composition system that is implemented into a simple, top-down shoot-em-up style game. An example of this kind of game would be Boxhead: Zombie Wars.

This research attempts to provide a solution to excess repetition in game audio. Consequently, the output of this research will be of interest to anyone who has an interest in game audio. Application of the algorithms used in this study will allow both sound designers and game music composers to create their own version of the system and implement them into simple games. In addition, other fields such as medicine could potentially find some benefit to the research outcomes as part of a therapy program.

Related Work

From a structural perspective, music as a whole is an extremely flexible medium, with few hard and fast rules on how to approach a composition. However, music can, in very general terms, be thought of as a combination of some number of melodic elements (i.e notes) played for some length of time (rhythm). While perhaps a gross oversimplification of the complexity of music, it is nonetheless a clear way to begin to understand musical structures.

Much research has been done on the relationship between rhythm, pitch, and emotion. For example, in a study undertaken by Hevner, [6], a strong link was found between various emotive states and particular rhythms and tempos. Ordered rhythms tended towards portraying more ordered emotions or ideals. In addition, chaotic rhythms also were found to have differing effects based upon perceived regularity. For instance, a chaotic yet rhythmically regular piece of music was shown to imply more exciting emotions. Perhaps unintuitively though, this particular study found that the direction of pitch (i.e ascending or descending) had little to no impact in the emotional responses of the participants.

Algorithmic Composition

Algorithmic composition is a blanket term used to describe any form of musical compositional technique that incorporates some form of algorithm, that is, a process, as part of the compositional journey [7]. In its most simple and basic form, this could mean the use of a random number generator to determine what note comes next. While considered by the uninitiated to be a relatively recent field of study, algorithmic composition traces its roots back much further than the last 60 years or so. One of the first recorded examples of a process used as part of composing music was found as a parlour game invented by Wolfgang Amadeus Mozart. As part of this game, people would take sections of music pre-composed by Mozart, assign unique numbers to them and roll dice to choose a section to use [8]. However, in modern times, algorithmic composition is generally used to describe the more specific field of Computer-Aided Composition.

Generally, there are three categories that algorithmic composition falls under. These three approaches are transformative, generative, and analytical. Transformative composition takes a pre-existing piece and applies algorithms to it to create variations. This category is similar to the commonly used compositional framework known as "Variations on a Theme". The second category, generative music, is used to describe the creation of music without any prior melodic data. The third category, analytical, can be considered to be a more extreme version of transformative, relying on careful compositional analysis and study of the harmonic, melodic and rhythmic parts of the pre-existing pieces of music.

Regardless of the category that the algorithm/s take, there will always be similar parts to the process. Jacobs [9] defines these components as the composer, who creates the music, the ear, which tests validity of the music, and the arranger, who compiles and arranges the tested music. The composer and arranger are often combined. While there is much debate [10] surrounding potential approaches and their perceived effectiveness, it is generally accepted that there are four main categories. These are: Chaos Theory and Dynamic Systems, Life-Like Processes, Rule-Based Grammars, and Stochastic and Probabilistic processes. For this review, the main focus will be on Rule-Based Grammars, and Stochastic Processes.

Stochastic Processes

Stochastic refers to any process that uses some form of randomness to generate the output. A Commonly used example of this approach are Markov Processes in which the probability of transitioning into one of several, finite states is determined by a transition matrix. Increasing the order of the transition matrix (that is, increasing the number of past states that are considered) will give a more accurate prediction of the next state. By setting each state of the process to either a single note or a cluster of notes, it is possible to use this predictive capability to compose music. However, as this is a predictive system, some form of source material is generally required to setup the initial transition matrix [7]. Markov processes are one of the most widely used approaches to algorithmic composition. However, the output of these creations are mainly concerned with one style of music per compositional engine.

Recently however, there has been research into morphing styles, with researchers [11] investigating methods of using Markov processes as a method of transitioning between different styles and modes. Wooller and Brown [11] used Markov chains as a method to transition between two pieces of music. By using a technique they called Markov Morphing, it was proposed that taking a transition matrix built from each piece and switching back and forth between each transition matrix, it would be possible to create a sufficiently smooth transition. This switching was done via a weighted selection. The process starts with the transition matrix of piece 1 being assigned a weight of 100%. Piece 2 has a weighting of 0. Over some transition period, the weighting of piece 1 approaches 0, and the weighting of piece 2 approaches 100%.

However, null predictions (i.e predictions that resulted in an invalid state) were an issue. To remedy this, Wooller and Brown [11] allowed the system to use the last transition matrix if a valid state could not be found. Following on, Wooler and Brown [11] found that the length of time that a transition took had a significant impact on the perceived smoothness. A short, (i.e 16 bars or less) transition period was found to not be sufficient for a smooth transition. The best transitions were found to be at or beyond 64 bars of length. In addition, the optimum position for a transition was influenced significantly by the phrasing of the piece. The end of a musical phrase was determined to be the best position to transition from.

Rule Based Formal Grammars

In mathematics and related fields (i.e computer science), there exists a form of logical construct known as a Formal Language. A Formal Language is comprised of a "set of finite length words (i.e. character strings) drawn from a finite alphabet" [12], much like any spoken or written language that is around today. In most cases, the set of words is infinite. Following this resemblance, a Formal Grammar is a mathematical construct that precisely defines (i.e delineates) a Formal Language using a series of tightly defined rules. More completely, a Formal Grammar (G) takes the letters used in the language (N), clusters of letters used in the language (S), and a start symbol (ω) and some number of production rules (P) to it [13]. This gives us, in set notation, G = {N,S,ω P}. Each complete application of all the rules is known as a derivation [12]. Chomsky Systems are one of the more well known kinds of Formal Grammars. However, there are others, such as Lindenmayer Systems, that differ in the application of the production rules. For example Chomsky Systems apply the production rules sequentially, while Lindenmayer Systems apply the production rules at the same time [12].

Lindenmayer Systems

A Lindenmayer System (L-System) is a type of simple fractal. L-Systems are often used to generate self-similar structures. In base form, the algorithm used to generate these structures is very simple. A string of letters or numbers is first generated. Then, for each unique element of that string, another string of numbers or letters is generated. Next, each element of the original string is iterated through and replaced by the corresponding generated string. This process is iterated as many times as desired. Traditionally, the generation of self-similar structures is used by biologists and bio-scientists [14] as a method to simulate particular growth patterns found in nature. However, the self-similar characteristics of L-Systems have been applied to algorithmic composition [12,15]. By mapping the strings of numbers and letters to notes, it is possible to create music that while not entirely cyclical, does have some repetitive elements.

Affective Algorithmic Composition

Affective Algorithmic Composition (AAC) is a term used to describe a perceptual and psychological approach to algorithmic composition [16] that is designed to elicit a desired emotion (i.e. affect) from the listener. While several models for categorising affective states exist, one of the first, and perhaps most commonly used models is the Circumplex Model of Affect [17]. This is a two-dimensional model that categorises affective states through the combination of valence and arousal. Valence refers to the perceived positivity or negativity of the stimulus, while arousal refers to the feeling of energy or lack thereof [18]. However, some [18,19] have advocated the use of three or even four-dimensional models, due to the complex nature of emotions. For example, fear and anger on the Circumplex Model of Affect both occupy nearly identical locations (that being somewhere on the low valence, high arousal area), but are very different in emotional impact [19].

Most attempts at algorithmic composition for affective purposes utilise transformative composition [18]. This is perhaps due in part to the innate difficulty of generating an effective affective piece from nothing [20]. [18] continues by showing that using seed pieces tailored to affective states gives a high amount of emotional correlation to the content displayed on the screen, but lowers perceived immersion for the majority of test participants. The authors' suggested cause for this is the instrumentation. "The original soundtrack might be lacking in emotional variation, but it offers a fullness and depth of instrumentation that is not easily matched by a single instrumental voice" [21]. The writers of this study suggest that a true generative approach utilising multiple voices rather than a transformative one relying on crossfading of pre-generated music may aid in remedying the reduction in immersion. However, the authors also note their small sample size and suggest increasing the number of participants will achieve a more robust result.

From this review, it is clear that a significant amount of research has been undertaken in the field of algorithmic composition. The application of affective models to algorithmic composition is still quite recent, with little solid practical application outside of a theoretical context detailed specifically for games. The only documented implementation with an affective evaluation of an affectively driven algorithmic composition system into a video game shows great promise in affective correlation, but has had a negative effect on player immersion (Williams et al., 2016). Consequently, there is a clear gap in regards to a true generative approach, specifically in the context of a game.

The project built as part of the research detailed in this paper aims to fill this identified gap found in the literature review. This will be done through the creation of a true generative system for a game. This builds on the work of prior researchers [19, 20, 21] and their attempts at creating an AAC system. This was achieved by taking parts of the approach detailed by Williams et al. [20] and combining it with the processes described by Prusinkiewicz [15]. The mapping of the parameters was informed by the investigations of both Hevner [7] and Wallis et al. [19].

Autonomous Music Composer

To build the algorithm used in this autonomous composer, several techniques were used. These techniques are detailed in the following subsections.

L-System Generator

This component of the algorithm generates the main harmony line. It uses a modified version of a Lindenmayer system to generate a simple, self-similar harmony. This component can be divided into two processing stages. The first processing stage is the definition of the production rules via creation of the base strings. The algorithm builds a string of user defined length out of the notes in the selected scale mode. This process is repeated for each note in the scale mode. After this process is complete, a short string is generated out of the notes in the scale mode. This string is the start symbol. The second processing stage takes the production rules created in the first and applies them *n* times, where *n* is a user defined value (as shown in Figure 1).

```
Let M represent the current musical mode; R represent root note; ω represent the initial note; P represent the production rules of the system; O represent the application of P to ω; O_n represent the nth derivation of P to O

Where ← means assigned as; ∈ means an element of

ω←random number r where r ∈ M
for each note N_M in M
    for i = 0 and i < x (x is char length of a production rule)
        if i ≡ x -1
            r ← r ∈ M
            N_M ← N_M + r //each iteration of the loop generates a new r
            else
                N_M ← N_M + r + s //where s is a character separator
                P ← N_M
for each N_M in M
    for j = 0 and j < n
        for k = 0 and i < M_N //where M_N is the number of elements in M
            if N_M ∈ O
                for l = 0 and l < M_N
                    if M_[l] = N_M
                        replace N_M with corresponding P
return O_n
```

Figure 1: Modified L-System Generator Algorithm

Composer

Before composition takes place, a state builder algorithm is used to generate the initial transition matrix. The composer can be separated into three sections. These sections are Rhythm, Melody, and Harmony. Both Melody and Harmony use note sets defined by specific musical scales. The scale degrees used, in order, from least positive to most positive are the Half-Tone Whole-Tone Scale, Phrygian Dominant, Natural Minor, Dorian, Mixolydian, Major, and the Pentatonic.scales. These scale modes are partitioned.

State Builder

This subsystem takes a List of notes and builds *n*th-order states out of it. Each state is represented as a string with the format: note 1,note 2,note 3,....note *n*. When building the states, the system wraps the input List to allow for consistent state lengths.

Melody

The generation of melody is controlled via the valence (perceived positivity). At specific valence thresholds, the algorithm swaps out the transition matrix it uses for one more suited to conveying the desired emotion. The notes themselves are chosen via a first order Markov chain.

```
Let F represent the function; M represent the transition matrix currently in use; S represent the current State; N represent the next note to play
if S ∈ M then
    R ← transition probabilities associated with S
    p ← randomly generated float between 0-1 inclusive
    for each  P in R do //Where P represents a probability in R associated with a note n
        C ← P - p
        if C ≥ 0 then
            N ← n_P // Where n_P is the note associated with P
                break
else
    S ← S ∈ M
    N ← F(N)
return N
```

Figure 2: Markov Chain Algorithm

Rhythm

Rhythm generation was controlled primarily by the level of excitement in the scene. High levels of excitement will create a more ordered and rhythmically regular piece of music, while lower levels of excitement will output a far more rhymically chaotic piece.

Harmony

Prior to outputting music, the composer calls the Lindenmayer generation system several times for each musical scale used. These outputs are stored according to scale type. Each scale's associated L-Systems are merged and then converted into a first order transition matrix. Then, a random L-System is chosen from the corresponding categories to be used as the harmony line.

Composition Algorithm Implementation

It was decided to approach the system from a pandiatonic perspective. Pandiatonicism is a compositional technique in which "each of the seven degrees of the diatonic scale are used in democratic equality" [22]. This is achieved partially by removing the root note. Without a root note, utilising each degree (mode) of the diatonic scale is far easier to achieve. In addition to the use of pandiatonicism, adding ambient sounding music not only tied into the pandiatonic principles defined earlier, but also removed much of the focus on melodic structure. Due to the scope of the project, greater focus was placed on the rhythm of the piece instead of the melodic elements. To test and prototype this approach, we use a free, open-source midi synthesiser library called C# Synth [23] as a base. This prototype consisted of three different modules: *Rhythm*, *Harmony* and *Ambient Melody*.

The first module, Rhythm, tested simple rhythm generation. This module used a weighted random selection as discussed earlier in Chapter 2 to determine the length of a note for any given BPM (Beats Per Minute). This prototype formed a kind of proto-Markov process. Firstly, the beat unit needed to be found. The beat unit (BU) refers to the length of a single beat in a bar. BU was calculated through the formula BU = 60 / BPM. Once this number was found, it could be subdivided it as required. In addition, as an affective model based on Russell's Circumplex Model of Affect [17] was being used at the time, it was reasonable to change the strength of the weighting based on valence and arousal. The weighted random selection was partitioned using a scale from 0 - 1 based on arousal, using assigned thresholds of 0.25. Arousal was chosen as the main affective parameter for rhythm. While quite crude, it cleanly and clearly demonstrated part of the foundation for the pandiatonic system.

The second component was created to test the implementation and effectiveness of some basic pseudo-melodies. Firstly, several celtic folk melodies were manually analysed for note pitches. Then, the frequency of occurrence of these note pitches were recorded. A zero order Markov chain was created by loading the frequencies into a transition table. The output, was, as expected, quite random, however, there was also a small degree of melodic output that could only be described as unexpected. This prompted further investigation and refinement of this component. The note immediately after each of the prior notes was found and analysed to create a first order Markov chain. The output improved in coherency, while still retaining much of the desired randomness.

As manually creating matrices from music was time consuming, a small program was written to scrape midi files for note data. This was achieved by finding each midi event message in the midi file with a status byte starting with 1000. This is a NoteOn event message. Then, each midi event that satisfied this criteria had the associated note value read and added to a list. This gave a full list of the notes in the piece. Afterwards, states were constructed based on a supplied number to determine the order. This enabled rapid testing of the impact of higher order Markov chains. However, this method of scraping midi files was only valid for single pieces that do not have any chords.

Using this program, we were able to rapidly test a variety of orders of Markov chains. It was found through personal testing that any order higher than one, while extremely musical, displayed too little randomness for the pandiatonic system.

The third part of the initial prototype was developed to test the generation of harmonies. A random choice between thirds and fifths were added to each note played. These particular intervals were chosen as they are extremely stable intervals, especially the fifth. The generated harmonies were added as in the second channel and third midi channels.

Combining all of these components created the first of many prototypes. Upon review, we agreed that while the pandiatonic principles were adequately represented, it didn't ultimately succeed. Pandiatonic composition requires deep knowledge and understanding of music theory to successfully implement. That level of theory was found be outside of the scope of our ability to implement in the time provided. Unfortunately these tests were ultimately for naught.

After the failure of the initial pandiatonic prototype, we investigated alternate solutions. An approach based purely on Markov Chains was not desired. A non-pandiatonic, pure approach is an already heavily investigated area, and consequently not enough research space was found for the period of time allotted. However, it was found that there was a lack of research and investigation into hybrid approaches. Following on, it was found that systems based on L-Systems and other grammar based approaches are not as thoroughly investigated as those based on Dynamic Systems or Life-Like processes. The hybrid approach was specifically chosen as a valid option as we wanted to salvage as much as we could from the old prototype. In addition, It was theorised that the self-similar characteristics of L-Systems would be well suited to the creation of basslines, which are commonly repetitive in nature. We translated the algorithm mentioned earlier into a system to test if this assumption had merit.

Experiment

Participants

A pilot study was undertaken to investigate whether the experience of the listeners reflected the emotional intent of the music produced by the algorithm. The sample selected consisted of 10 subjects recruited from a pool of students from the University of Canberra Game Development Club. All participants were male.

Data Set

10 pieces of music were generated by the algorithm, with specific input parameters, as shown in Table 1.

Piece	Valence	Arousal
1	8.5	7
2	3	3
3	1	5
4	2	6.5
5	7	5
6	5	8
7	3	2
8	8	1
9	4	4.5
10	1	5

Table 1: Values used to generate pieces

Procedure

Each participant was placed in front of a computer with a pair of headphones supplied. Each participant was given ten (10) pieces of music generated by the algorithm. Each piece of music was between fifteen (15) and twenty (20) seconds in length. Each participant was asked to assign values to the pieces according to perceived positivity (valence = V) and energy (arousal = A) levels using an 11 point Likert Scale. Afterwards, there was an opportunity to complete an open response field if there were any further comments. The results were collated and the mean and standard deviation of each group were calculated and are presented in Table 2.

Results

Sample	Expected	Mean	Standard Deviation
P1 V	8.5	7.9	1.52
P1 A	7	6.7	1.67
P2 V	3	2.7	2.71(1.05)
P2 A	3	2.4	0.82
P3 V	1	1.2	1.23
P3 A	5	4.3	0.95
P4 V	2	3.8	1.55
P4 A	6.5	5.3	1.25
P5 V	7	6.4	1.07
P5 A	5	6.4	1.17
P6 V	5	5.1	1.20
P6 A	8	5	1.25
P7 V	3	3	0.52
P7 A	2	3.7	2.11
P8 V	8	4.6	1.43
P8 A	1	3.1	0.99
P9 V	4	6.4	1.71
P9 A	4.5	5.4	1.89
P10 V	1	1.3	1.11
P10 A	5	3.1	0.53

Table 2: Statistical Summary showing mean and standard deviation of the results of the questionnaire

Discussion

The means of the sample group seem to closely mirror the expected input of the algorithm. The minimum difference (d) of 0 occurred in P7 V. The maximum d of -3.4 occured in P8 V. Otherwise, most of the other music samples have d =< ±1. The standard deviations of the survey participants ranged from 0.52 to 2.1 (note that P2 V contained an extreme outlier, which when removed reduced the standard deviation to 1.05).

Analysis of the data supports the purpose of the algorithm. By this, we mean that the participants seem to have had an experience that matched the intent of the algorithm's generated music. With the exception of P7 A, the experiences of the participants were relatively close to the expected value. Additionally, even when the experience of the participants deviated from the expected input, the participants experienced a similar response, as shown by the relatively small standard deviations.

There appeared to be the greatest difference in P8 for both V and A. The levels were intended to generate a piece with a high valence and a very low arousal level. The characteristics of a high valence, very low arousal piece include calmness and relaxing. However, it appeared that the very low arousal level may have in fact masked the high valence level, causing participants to react negatively to the piece.

There are several limitations to this study that may have had an impact on the results. Firstly, the small sample size. A larger sample size would almost certainly improve the validity of this data. Secondly, all the participants were of one gender. The addition of female participants may have some impact on the outcome of the experiment. Further investigation into increasing the sample size is planned.

Conclusion

In this paper, we detailed our attempt to create an AAC system. The approach to composition was a hybrid of Lindenmayer Systems and Markov Chain theory. The system is a truly generative system, generating it's music as the game progresses. Evaluation of the system shows a high correlation between the experience of the listener and and the music generated by the algorithm. Additionally, testing the algorithm gave valuable insight into potential future research avenues. Some of these occur through flaws in the research, while others appear as and refinements to the algorithm used. Additionally further research should be done on morphing algorithms in the context of short transition times or perhaps the effect of the addition of musical layers depending on excitement.

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Plug-ins, Presets and Practice: The Impact of Digital Technologies in the Context of Contemporary Music Production

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Abstract
Not only has digital technology affected the way we purchase and listen to music, it has also transformed the way song writers, composers and producers create. Mobile applications and laptop computers allow composers the freedom to make music anywhere, implementing a myriad of music making applications, software programs and plug-ins designed to simplify and democratise the production process. The previously vast and complex arts of music composition and production are now accessible to everyone and accordingly, traditional methods of music composition and production are no longer standard practice. This paper explores new standard methods of composition and production through the creation of a commercial song. Using Apple Voice Memos to assist with conceptualisation and composition, computer-based methods to record, arrange and mix, and the Internet for automated mastering, this paper illuminates a new standard in creative practice, and redefines traditional roles such as music composer, music producer and sound engineer.

Keywords
music, composition, production, apps, mobile, techniques, producer, composer, iPhone, Pro Tools, GarageBand, Voice Memos, Music Memos, Notes.

Introduction
In the last few decades, the widespread application and integration of digital technology has profoundly impacted society and industry. The digitisation of music has had vast implications for the distribution, promotion and publishing sectors of the music industry, causing old business models to evolve or become obsolete. Reflecting this shift, in 2016, digital revenues made up fifty percent of global recording industry revenues, as opposed to physical format sales which generated thirty-four percent [1]. Streaming, through platforms such as Spotify, Apple Music and Google Play are now key to the consumption of music, deriving fifty-nine percent of all digital revenues [1]. Furthermore, due to the simplicity and affordability of distribution services such as Tunecore and LANDR, virtually anyone can release their own music in just a few clicks of a mouse, using social media as a promotional tool. Recently, technological innovations have had material consequences with regard to music composition, performance, recording, arrangement, engineering and production. Up until the 90's, the recording studio had been the epicenter of popular music production; often, studios comprised of bulky, expensive and complex analogue hardware such as multitrack tape machines and mixing consoles. Now, due to the digitalisation of the recording studio itself, many large-scale studios have downsized or shut down completely. As Leyshon [2] points out, the viability of the traditional studio model is less financially sustainable, directly affected by the advent of the Digital Audio Workstation (DAW). Signaling a new age of music production, the widespread use of DAWs inspired the phrase 'in the box' (ITB), describing the integral role of the computer as the hub of musical creativity. In a historical turning point, Ricky Martin's hit single, 'La Vida Loca' [3] was the first global hit to be recorded and mixed entirely ITB [4]. Around this time, emulations of music production technologies (such as signal processing plug-ins) had become widely integrated into amateur and professional workflows alike. A statistical analysis by Paul Théberge [5] indicated that the technology used to produce internationally successful recordings is in many cases the same and is available to anyone with a personal computer, at a relatively small financial expense.

Innovative approaches to practice are often a direct consequence of technological developments, and one of the key affordances of digital technologies within music production is increased accessibility, affordability, autonomy and creative agency, enabling an individual to undertake the roles of composer, engineer, editor, arranger, mixer and producer. Describing a functional typology of music producers, Richard Burgess in his book, 'The Art of Music Production' [6] points out that artists who produce themselves are the simplest of all categories. Recalling historical examples such as Les Paul, Stevie Wonder and Prince, Burgess [6] also refers to artists of recent times such as Gotye and Calvin Harris, expounding on the growing prevalence of the artist-producer typology due to the democratising effects of digital technologies. Supporting this claim, Strachan's [4] in depth analysis of the UK top 30 in a random week of January 2015 found that 21-year-old Phillip George, whose single 'Wish You Were Mine' was at number 2 on the charts, produced the song in his bedroom studio using Logic. Furthermore, artists such as Australia's Tame Impala (aka Kevin Parker) are achieving global commercial and critical success, receiving two Grammy award nominations for his albums Lonerism [7] and Currents [8], of which he almost entirely wrote, recorded, mixed and produced himself. The objective of the present study was to document the music production process, demonstrating the link between digitisation of technology and the democratisation of music production. Methods used involved recording voice memos (Apple Voice Memos), writing notes and lyrics (using Apple Notes), making screen and audio recordings and mastering. The aim of this study was to better understand the implications of democratisation and to further consider the role of music producer, composer and engineer. As reflected in the results, a gargantuan shift in the music production industry is occurring as a result of digitisation.

Context

Directly related to the possibilities afforded by new technology is the innovation of novel approaches to practice. As part of the foundation of my overarching argument I contend that terminology, semantics and language choice in the context of contemporary music production must be further refined, giving substantial consideration to the impact and practical implications of current music production methods. A cutting edge method is characterised by many different approaches to performing, recording, editing and mixing, in order to create a 'reality of illusion' [9]. This particular aspect of my argument aims to expand on the significance of previous findings in the literature forming a strong foundation upon which to advance an improved framework. The suggested framework utilises the term 'produce' to describe a holistic, integral and recursive approach to computer-based music-making as distinct from sequenced music [10]. In relation to the evolving role of the producer, Zak [11] points out that traditional meanings of terms such as 'composition' must be expanded upon, if they are to be understood in a contemporary music production context.

The term 'compose' and 'composition' (as they relate to music generally) convey classical notions such as 'scoring'. However, these terms also carry with them a "set of normative associations that characterise some but not all of what people do when creating music through production" [12]. This being so, there is a dialectical need to either modify contemporary nomenclature, or alternatively adopt a definitive and more appropriate term (as typified by accuracy and specificity with regard to actual practice). The term 'song writing' is synonymous with the process of composing a piece of music, particularly as it relates to original contemporary music. As Zak [11] points out, 'song writing' usually refers to the "creation of music with lyrics, harmony and melody, often represented in the form of a lead sheet or loosely notated version of the music". When considering current trends and practices within contemporary computer-based music making, the implications are overt. For example, through the use of multitrack recording techniques and technologies, song writing may occur simultaneously with recording [10][11]. This approach to music production is crucial to an argument for a revised framework because it challenges and questions the very concept of recording in relation to its traditional purpose as an 'act of preservation' [12].

In his book, 'The Poetics of Rock: Cutting tracks, making records' Albin Zak [11] suggests a framework for understanding contemporary music production, placing an emphasis on the compositional elements of the final recording. Zak's [11] view contends that recording consists of "three compositional layers: the song, the arrangement and the track". Whereas a 'song' can be performed and is represented by a lead sheet, usually including words, melody and chords, the 'track' necessarily refers the recording itself". This framework is fairly useful in describing contemporary music practice and is adopted by Tobias [12], in his paper 'Composing, songwriting, and producing: Informing popular music pedagogy'. Tobias' [12] qualitative research draws upon a single intrinsic case study, focusing on secondary students' creation and production of popular music. Reflected in many earlier studies [12][13][14] a correlation between Formal Instrumental Music Training (FIMT) and production approach was found. For example, students who did not have FIMT more frequently used the capabilities of the computer in place of instrumental skill [13]. Tobias [12] points out that "all participants produced their music through mixing and editing to varying degrees, at different points, and idiosyncratically throughout their overall process". To give an example of when this occurred Tobias [12] describes the process 'Marcus' and 'Liz' went through in recording, mixing and editing their production 'Here'.

For Marcus and Liz, recording and mixing played a pivotal role in their creation of 'Here' even though it occurred after they had created and practiced performing 'Here' as a song. Once they began recording, Marcus constantly edited the track through deleting extraneous noise or mistakes and adjusting input and volume levels [12].

Subsequently, Tobias [12] states that "mixing was not necessarily separate from recording or editing … In fact, many students mixed and recorded their music in a simultaneous and recursive process". Although the term 'recursive' is used in this case to describe a particular approach to recording, editing and mixing, Tobias [12] later expands on this, including 'create' and 'practice' in his description of potentially recursive processes.

An important development in Tobias' [12] study centered around 'Alice' and her creative process, which consisted largely of manipulating Musical Instrument Digital Interface (MIDI) information in a recursive fashion, characterised by the integral use of Pro Tools (in relation to the creation of her production). Due to this particular production approach, Alice's song did not exist outside the virtual environment of a Digital Audio Workstation (DAW). Tobias [12]. Expanding on the significance of this phenomenon, Tobias [12] stated that "editing was an integral aspect of Alice's creative process and inseparable from her idea generation, development, recording and mixing".

The concept of creating a 'reality of illusion' as postulated by Virgil Moorefield [9] is closely related to the 'recursive' production approach Tobias [12] describes. Whereas recorded music has traditionally been characterised by a singular and coherent performance (an 'illusion of reality'), creating a 'reality of illusion' consists of copying, cutting, pasting, moving, editing and otherwise manipulating digital audio regions (made up of discrete performances), in an act of creating a single, unified performance which never really existed [9]. Tobias [12] found that "Students regularly recorded, mixed and edited their music to create recordings of 'performances' that would have been impossible without the use of technology … Ensemble performance was thus constructed rather than performed live and organically" [12]. While this cutting-edge approach to production may be seen as an inauthentic approach to music making, it is arguably a key component of contemporary music production; its implications are far-reaching in relation to the innovation of musical styles and genres, simultaneously enabling those without FIMT to create music on a commercial level. This shift in paradigm has a great deal to do with the evolution of producers and is exemplified by the prevalence of 'artist-producers', as credited on many commercially and critically successful albums of recent times.

Methodology

This practice-based research project seeks to investigate the impact of digital technologies (such as digital signal processing plugins, virtual instruments and presets) in the context of contemporary music production. By employing a practice-based methodological approach utilising contemporary music production methods and techniques, this project will offer a unique insight into the real life impact of digitisation and democratisation.

Song Creation Process

Composition Using Apple Voice Memos

The composition process consisted of four phases: planning, performing/recording, reviewing and reflecting (see figure 1), characteristic of an action research cycle. This cyclical process was recapitulated until the song was fully composed. In practice, composition began with the conception of a melodic phrase. The melody was sung out loud and recorded using Apple's Voice Memos application. Having memorised the phrase through repeated listening, I then performed it on an acoustic guitar which helped to visualise the position of the notes on the guitar fret board. This process was useful in determining the musical key of the melody, guiding decisions related to the underlying chord structure. Having quickly worked out a few conventional chords to play in support of the melody, an experimentation period commenced incorporating alternative chords and variations on the melodic phrase; this occurred in an improvisational manner and was also recorded using Voice Memos. In an effort to affect the mood of the music (at that particular point of its conception), the melody and chords were transposed from the key of E major to the key of E minor. Having experimented to a small extent in this key, I soon realised that the revised melody (having changed somewhat due to the transposition process) was now based in the key of G major, the related major key of E minor. By making another Voice Memo recording, the main chords and provisional vocal melody were again revised. At this point, it seemed clear to me that the section I'd been working on would work as a chorus due to the perceived catchiness of the part. By repeating the same process, the verse and bridge sections were also created.

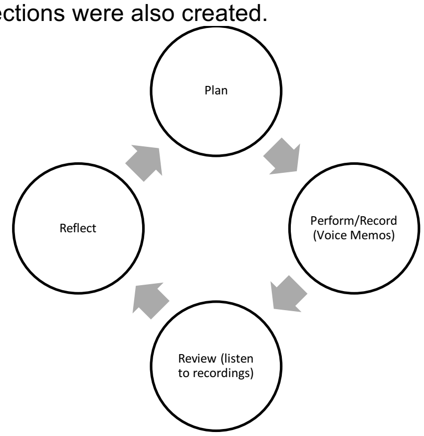

Figure 1: Composition cycle using Apple Voice Memos.

Finally, having composed each section of the song, the structure (including chords) were written in Apple Notes (see figure 2).

Figure 2: Song structure written in Apple Notes.

Song Production using a Digital Audio Workstation (DAW)

Upon opening the Digital Audio Workstation (DAW) application within which the track was to be produced, a new blank session was created using default settings (44.1kHz sample rate, 24-Bit depth and .WAV file type). This new blank session consisted of a single 'click track', automatically generated by Pro Tools.

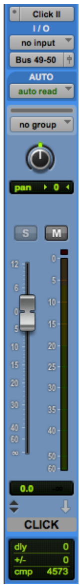

Figure 3: Click track channel.

Similar in function to a traditional metronome, click tracks play a crucial role in affording contemporary musicians an auditory guide related to the project tempo and meter. The first step in adjusting the tempo to suit the present project consisted of highlighting the session tempo (automatically set to 120 beats per minute) and listening to the most recent Voice Memo recording of the song I had composed. Using the recording as a guide and tapping the 't' key on my iMac keyboard for each beat of each bar, I was able to 'tap out' the tempo of the song. This process helped to establish a tempo of 180 beats per minute (BPM) in 4/4 meter (otherwise known as common time).

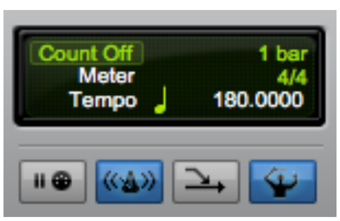

Figure 4: Section of Pro Tools' 'transport window' showing 4/4 meter and 180 BPM tempo.

Having made these adjustments to the overall session settings, the click track would now sound on each beat of each bar (four beats per bar, accenting the first beat of each bar) during playback or recording. This enabled me to perform 'in time' with a set tempo and time signature (meter), simultaneously defining the parameters of Pro Tools' grid mode, allowing many crucial procedures such as precise editing and features such as tempo syncing to occur later in the project.

Figure 5: Pro Tools' 'Click II' plug-in.

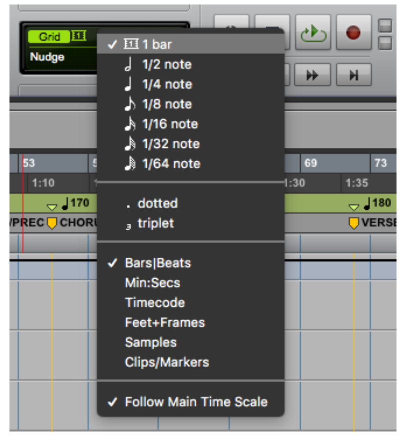

Figure 6: Pro Tools' 'Grid' mode parameters.

Upon deciding to record an electric guitar first, a new audio 'track' or 'channel' was created and a signal processing plug-in was added to the first insert of the corresponding channel (Waves Audio's GTR 3 'Stomp 4' amplification software). As is common with regard to the visual aspect of many digital plug-ins, this plug-in visually resembles its hardware counterpart (an electric guitar pedalboard, running from left to right in terms of signal flow). By adding a virtual 'fuzz' pedal from the pedal selection menu and selecting a preset, the tone of the guitar was dramatically altered, appealing to the sonic aesthetic I'd imagined would suit the project at the outset.

Figure 7: Waves GTR 3 with 'Fuzz' pedal.

In this particular situation, a 'Direct Input' (DI) analogue audio signal was generated by the electric guitar and subsequently captured digitally. By inserting a signal processing plug-in such as Waves' GTR 3's 'Stomp 4' in the virtual environment of a DAW, the digital audio signal was processed in a potentially reversible act, effectively altering the sonic quality of the recorded sound (while conforming to the particular limitations imposed on the captured audio, due to the fundamental sonic characteristics of the DI guitar signal generated the analogue audio domain).

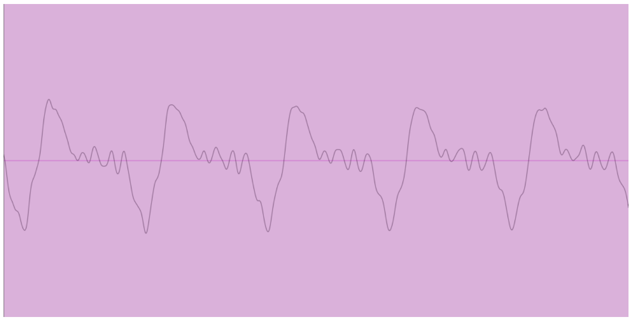

Figure 8: Captured DI electric guitar signal (digital) represented as a waveform.

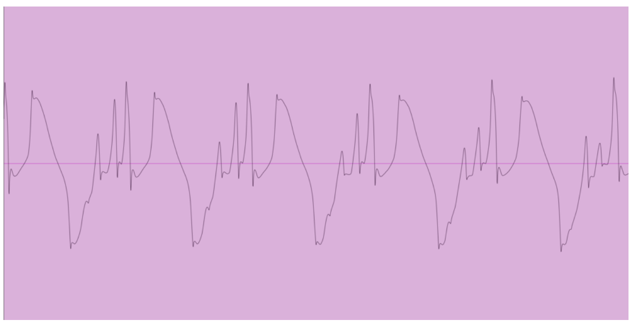

Figure 9: The effective tonal change as a result of Waves GTR 3 'Fuzz' pedal processing, visually represented as a digital waveform.

Figure 9 illustrates the introduction of digitally generated harmonic content (pertaining to the DI electric guitar signal) captured in Pro Tools. Because signal processing occurred in the digital audio domain, I was able to revert back to the sound of the original audio signal by removing or bypassing any plug-ins in the audio channel's chain; this flexible functionality is intrinsic to digital audio workflow. At many points in the creative process, 'tweaking' (alterations) occurred to the parameters of many plug-ins, which were set much earlier in the production process. In a few instances, entire processing chains were removed to reverse sonic and aesthetic decisions previously made.

Figure 10: Recording the first guitar track with Waves' GTR 3 'Stomp 4' plug-in inserted.

Adding Timeline Markers

Having recorded a 'guide' guitar track, the next process which took place was the simple addition of timeline 'markers'. The purpose of the following process was organisational in nature and helped to demarcate each section of the song for simple and efficient editing and tracking. Alternatively, timeline markers could be used to indicate points of interest, mistakes in recordings and other useful information. Using timeline markers to visually map out the structure of a song is particularly useful when using the DAW itself as a compositional tool.

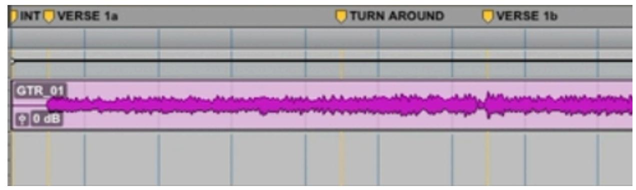

Figure 11: Placing markers as visual cues.

Adding Tempo Changes

In the process of setting out markers for each section of the song, it seemed clear to me that the chorus would sound better at a slower tempo (based on a subjective feeling). This required the tempo to slow down instantly on the appropriate beat. By creating two additional tempo markers – one on the first beat of the chorus section at 170 BPM, and one on the first beat of the following section at 180 BPM, this change was easily made (see figure 15). An attempt was made at slowing the tempo down over the course of a bar or two (using the linear tempo operation function), however these attempts were abandoned as the results were not preferable. Importantly, the timeline, click track and any other devices, tools or features dependent on the session tempo (and thus relating directly to the 'grid') were affected by these tempo changes.

Figure 12: Tempo change markers added, 170 BPM and 180 BPM.

'Dropping-in'

Because the tempo had changed in the chorus, it became necessary to re-record the electric guitar in that particular section. The useful 'drop-in' or 'punch-in' feature inherent in most DAWs was utilised to seamlessly record the appropriate part at the correct tempo. By setting the 'drop in' location to the first beat of the chorus (in Pro Tools' 'grid' mode) and the 'pre-roll' length to one bar, I initiated the process. This caused the click track to commence and the electric guitar track (which had been correctly recorded in the previous section) to sound for one bar, before automatically recording at the specified location. Although 'dropping-in' existed in analogue music production, it was a much more complex and fraught procedure due to the destructive nature of the analogue recording medium (magnetic tape). In many cases, dropping-in traditionally involved recording over an older performance; whether a better performance could be captured was often subject of heated debated [15].

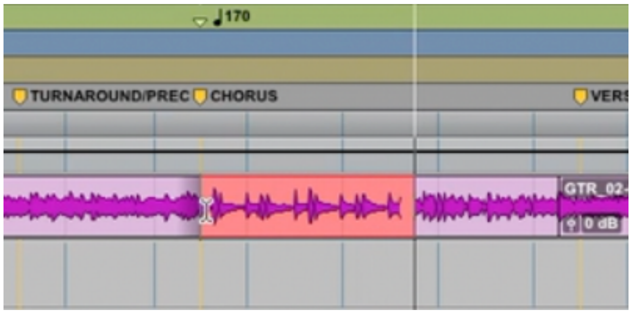

Figure 13: Having changed the chorus tempo to 170 BPM it was necessary to re-record the guitar part at the correct tempo using the 'drop-in' feature.

Virtual Instruments and Musical Instrument Digital Interface (MIDI) Sequencing

Subsequent to mapping out the structure of the song using markers as a visual guide, I then added a temporary electronic drum beat using a virtual instrument. As I had imagined the drum pattern during the composition stage of production, this process consisted simply of creating a stereo (virtual) instrument track, inserting a stereo instrument onto the channel (in this case Pro Tools' bundled drum machine 'Boom' by AIR Music Technology) and creating a MIDI region. While in the 'MIDI Editor' window the 'Pencil tool' (Free Hand) was used to create MIDI notes of the same velocity and length (according to the 'note division' specified by Pro Tools' 'grid' mode) in the appropriate pattern. In the figure below, each MIDI note corresponds with a different aspect of the Boom instrument, such as the 'Kick', 'Snare' and 'CL HH' (closed hi-hat).

Figure 14: Boom drum machine and MIDI Editor window in background.

A single bar of drums was created and 'looped' using the 'loop trim tool', producing a repeating drum beat throughout the entire song. Importantly, MIDI notes created in the MIDI editor window conformed to the tempo change in the chorus section automatically. In this case, MIDI note information was manually 'drawn' into an empty MIDI region using the 'Pencil tool'. Alternatively, MIDI information could have been recorded as a live performance, using a MIDI controller device such as a keyboard or drum pads. By recording a performance in this way, it would have been possible to quantise the MIDI note information, forcing the recording to conform to the 'grid' (as specified by the user), creating a performance in perfect time with the session tempo.

Audio Quantisation

The next procedure relied on the heavy use of 'Beat Detective', Avid Pro Tools' audio quantising tool. The following definition comes directly from the Pro Tools 12.8.2 manual:

"Beat Detective is a powerful tool for analysing, editing, and manipulating audio or MIDI data that has an inherent rhythmic character. Beat Detective analyses an audio or MIDI selection, identifies its peak transients or accented notes, and generates beat triggers based on the detected peak transients or MIDI notes" [16].

Audio quantisation is therefore extraordinarily helpful in 'tightening up' an audio or MIDI captured performance.

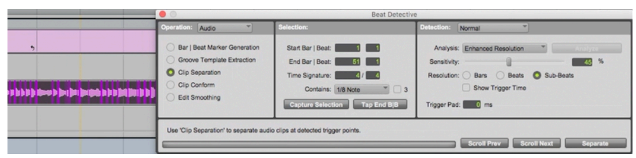

Figure 15: Beat Detective in 'Clip Separation' mode.

The audio quantisation process in this case involved selecting the electric guitar audio region by double-clicking the audio waveform, selecting the 'Clip Separation' operation in the Beat Detective window, choosing the appropriate note division and clicking the 'Capture Selection' button followed by 'Analyse'. This procedure generated 'beat triggers' (purple in colour) according to the analysis setting, 'Sensitivity' setting (on a scale from 0% to 100%) and 'Resolution' setting (Sub-Beats). Having defined these parameters according to the desired outcome, the 'Separate' button created slices in the audio region, at each individual beat trigger location.

The next step in quantising the performance was to make individual audio regions conform to the grid as specified, using the 'Clip Conform' function and associated parameters.

Figure 16: Beat Detective in 'Clip Conform' mode.

Finally, the last step in the quantisation process involved employing the 'Edit Smoothing' function. In doing so, Beat Detective created fades and crossfades (according to parameters I had defined) in an attempt to overcome clicks, pops and other undesirable artefacts (which may have been caused as a consequence of the previous steps). Having completed the Beat Detective process, it is sometimes necessary to edit the 'tops' and 'tails' of each (or some) of the affected audio region/s (depending on the analysis of the 'Clip Separation' function and the 'Edit Smoothing' function, as well as the accuracy of the performance itself in relation to the session tempo). In this case, some editing was required, implementing the use of the 'Trim' tool and the 'Crossfade' tool. Overall, the process of audio quantisation markedly improved the rhythmic aspect of the electric guitar recording, assisting in 'tightening up' the performance and engendering the desired sonic outcome.

'Comping'

Having recorded acoustic drums, quantised the corresponding audio regions (using Beat Detective), and edited them appropriately (in a corrective fashion) [10] using the 'Trim', 'Sector' and 'Crossfade' tools, I decided to 'comp' the drum tracks with the aim of creating a 'reality of illusion' [9]. Motivating this decision was a desire to create a unified drum performance which had a high level of sonic and rhythmic consistency. In this particular instance, the quantised/edited audio regions were selected as a group, based on particular criteria (such as sonic consistency), copied and then pasted onto the timeline (into the corresponding audio tracks) using Pro Tools' 'grid' mode. The aim of this procedure was to create the best 'take' of each particular section of the song. For the most part, only small segments of audio regions were required to create the necessary sections (using copy and paste), which were then looped as necessary.

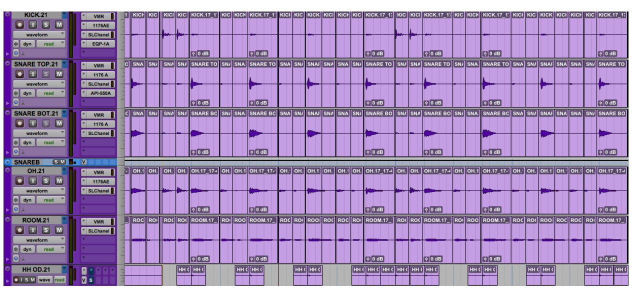

Figure 17: Creating the best 'take' using a 'comping' technique.

Sampling

Subsequent to creating a 'reality of illusion' [9] through the process of comping, the audio regions which corresponded to the 'KICK', 'SNR TOP' and 'SNR BOT' audio tracks were each replaced with a single 'kick', 'snare top' and 'snare bottom' sample respectively (leaving the 'overhead' and 'room' audio regions in their present state). The audio samples (or individual 'hits') I utilised in this process came from the same project session, and were chosen according to clarity and other sonic characteristics such as attack and decay.

Figure 18: Manually sampled 'kick', 'snare top' and 'snare bottom' audio regions placed on the timeline (Note: each track is comprised of a single audio region or 'sample' which has been copied and repeatedly pasted using the comped performance as a guide).

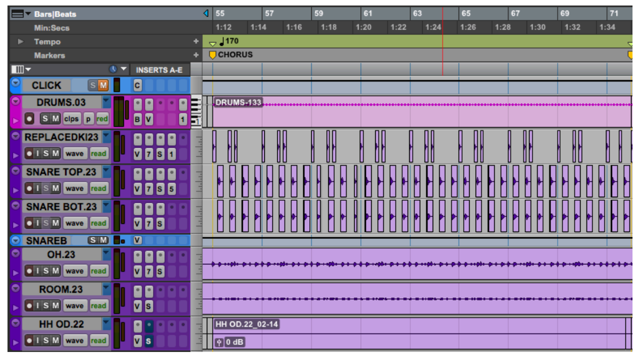

Figure 19: The only audio tracks from the acoustic drums take to remain intact after the initial comping process were the 'ROOM' and 'OH' tracks.

Manual Tuning Using Waves Tune

Having recorded a multitude of vocal performances and subsequently comped together a single vocal track (using edit tools such as 'Trim', and 'Crossfade'), the next step in producing a professional contemporary vocal track involved manually tuning each note using Waves Tune.

Figure 20: Multiple audio regions 'comped' together to create a single take.

The manual tuning process (as it pertains to Waves Tune) consists initially of 'Scanning' the audio region to be tuned (which detects the audio pitch and creates an initial correction curve) [17]. This process is initiated by inserting the plug-in on the corresponding audio channel and having the song (or the audio track to be tuned) play from start to finish. Having scanned the entire audio track (in this case the vocal track), I then engaged in manually correcting each vocal 'note' (see figure 22) using the 'Note' tool, 'Slice' tool, 'Glue' tool, 'Pencil' tool, 'Curve' tool and 'Line' tool.

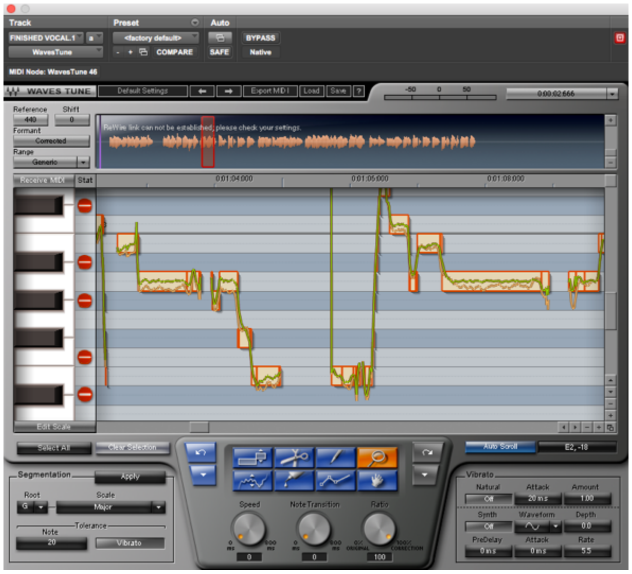

Figure 21: Manually tuning vocal performance using Waves Tune.

The largest portion of Waves Tune' Graphical User Interface (GUI) is made up of the 'Pitch Edit Area' and 'Notes Grid', visually representing the separate melodic pitches of the scanned audio region/s. To the left of the 'Pitch Edit Area' is the 'Note Status' and the 'Piano Roll'. Having set the 'Root' note to 'G' and the 'Scale' to 'Major'' the 'Notes Status' displayed 'Illegal Notes' (notes not in the specified key), represented by red circles with a white line through them. Assisted by visual cues (relating to Waves Tune's GUI), and guided by actively listening to sections of the vocal track in the context of the song (often repeatedly), it was possible to make appropriate adjustments to the pitch of each note that had been sung.

Final Mix

The final mix simply consisted of tweaking plug-in parameters relating to compression, equalisation and panning, as well as adjusting effects such as reverb and delay. Having made many mix decisions 'on the fly' during the production of the track, only small adjustments were required. As a sonic guide, I used The Strokes' song 'Machu Picchu', from their record, 'Angles' [18]. Manually writing in a small amount of level 'automation', I was able to control channel faders (or levels) over the course of the song. For example, I automated the guitar and synthesiser tracks, pushing the levels up a few decibels in the final chorus to add impact. Lastly, using Waves 'PAZ Analyzer' I was able to visualise the spectral features of the track.

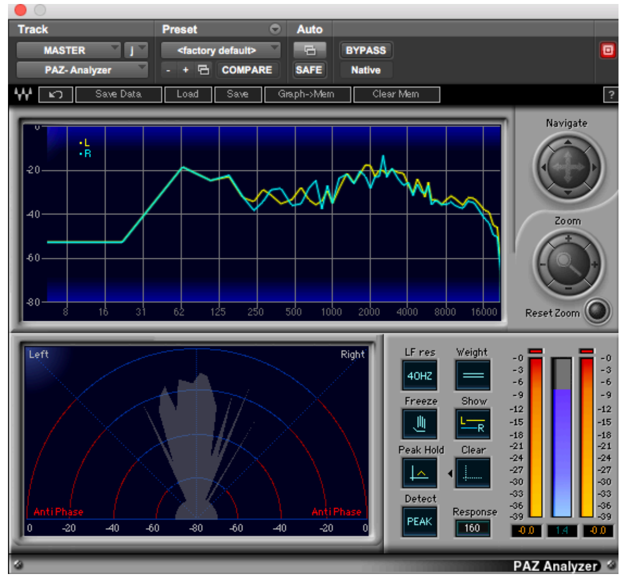

Figure 22: Waves' 'PAZ Analyzer' on the 'Master' output channel.

Mastering

Having 'bounced out' the final audio mix-down (creating a single, digitally uncompressed 24-Bit stereo audio file) I then uploaded my track to LANDR's servers. Within ten minutes LANDR had mastered the track and readied it for review. During the review stage, three options relating to the level of mastering 'intensity' were available to me. The setting chosen in this particular instance was the 'HI' (loudest) setting.

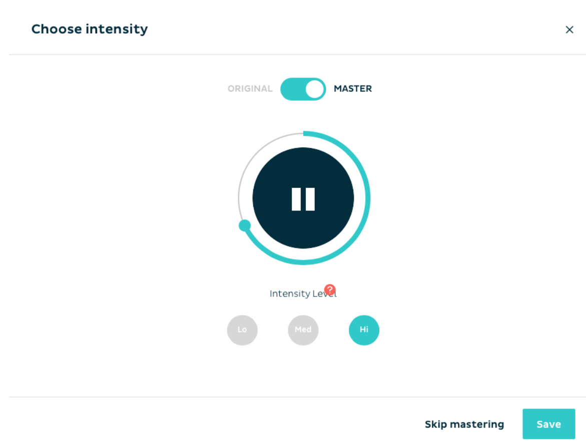

Figure 23: LANDR online automated mastering system.

Findings and Conclusion

By documenting, describing and demonstrating the production process of a contemporary pop song, it is possible to observe the many instances in which digital technology aids and assists the user in the creation process; from capturing ideas, recording, quantising audio regions, fixing the pitch of vocal performances, to creating a unified drum take which never existed, it is clear that the digitalisation of the music production process has had vast implications for songwriters, producers, sound engineers and an entire industry. The do-it-all songwriter/producer/ engineer, and the digital disruption of the music industry through the rise of do-it-yourself technologies, plus a plethora of affordable online services like mixing, mastering and distribution, affirms a need to redefine traditional industry roles/professions altogether.

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Generating a Virtual Forest Environment Using Procedural Content Generation

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Abstract

Video game worlds are growing rapidly, creating a large amount of content that digital artists need to produce. To cope with this amount of content, game development companies would have to hire more artists and content creators, which is not economical. Therefore, Procedural content generation (PCG) techniques have quickly become a key area in the development of video game worlds. These techniques can be applied to generate a wide variety of things, from entire forests to the individual leaves on a tree. Simulated real-time virtual forests are one of the more common and complex virtual environments in contemporary video games that have to be generated procedurally. In this research, we developed a system that integrates different PCG techniques to automatically generate and simulate a virtual forest in real-time. These techniques include Height Generation, Terrain Texture Generation, Detail Generation, Point Generation, Shadow Map Generation, Life Cycle Simulation and Day/Night Simulation. The implemented day/night system accurately calculate angle of the sun through the time of day to simulate life cycles of all flora in the environment in real-time. The optimized developed system can be easily integrated with any real-time game that requires a forest environment.

Keywords

Game Content Generation, Forest Generation, Real-Time, Procedural, Virtual Environment, Forest Visualisation, Simulation.

Introduction

As the target audience of video games gets larger, so too does the worlds within them. Video game worlds have evolved from small, individual levels to massive sprawling environments over the span of the past three decades. Because of these changes to video game worlds, the sheer amount of content digital artists need to produce is immense. To combat this avalanche of content, game development companies have developed automated techniques for generating content. These are known as procedural content generation(PCG) techniques, and they can be applied to generate a wide variety of things, from entire cities to each individual leaf on a tree (Hendrikx et al, 2013).

Virtual forests are one of the more common and complex virtual environments in contemporary video games that need to get generated procedurally. These complex virtual environments require many objects to populate them, ranging from small mushrooms to century old trees. The geographical aspects of real forests can differ greatly, so any virtual representation of them needs to be very flexible in their implementation. Each tree in a forest should be similar in many aspects to its neighbours, yet also requires some sense of individuality (Ch'ng, 2011). To achieve a virtual forest with all these required objects and characteristics we propose to combine different procedural content generation techniques. We take certain optimizations into account when combining the techniques to get the autonomous forest rendered at real-time. Real-time means the forest environment will be rendered and updated approximately in sixty frames a second. The autonomous forest will be developed in the Video Game Engine (VGE) Unity. The end product will procedurally generate entire forests autonomously, from the overall shape of the environment, to the simulation of floral growth.

Related Works

There are numerous ways of implementing procedural distribution and placement including Poisson Disc sampling (Kailkhura et al, 2016; Park et al, 2014; Park et al, 2017; Ying et al, 2013) and Realistic Spatial Distribution (Lane & Prusinkiewicz, 2002). These techniques have their own advantages, with Poisson Disc Sampling being great for quick, uniformed and random placement, and Realistic Spatial Distribution being able to generate exceptional realistic plant ecosystems.

Poisson Disc sampling is a procedural point placement algorithm that evaluates each placed point and makes sure they are a certain distance away from their neighbours (Ying et al, 2013). This leads to a random, yet uniform distribution that provides a useful data set for many different applications such as "anti-aliasing, global illumination, non-photorealistic rendering, re-meshing, texture synthesis, and vector field visualization (Ying et al, 2013). In comparison with the other procedural placement techniques, Poisson Disc sampling is the optimal algorithm when requiring evenly yet randomly distributed points as techniques like Uniform Random Distribution and Jittered Grids possess too many opportunities for unwanted clumping.

Another solution to procedural object placement provided in a paper by Jane and Prusinkiewicz (2002). This paper dives into extremely realistic plant placement via multiset L-systems, with each plant spreading their own seeds into the virtual environment. An L-System, otherwise known as a Lindenmayer system is type of formal grammar, consisting of an alphabet of user-defined symbols. The L-System adheres to specific 'production rules' that are used to expand each individual symbol into larger sets of strings. Then, after generating these strings the L-System employs a mechanism to translate them into geometric shapes and structures (Suhartono, Hariadi & Purnomo, 2012).

Jane and Prusinkiewicz (2002) cleanly defined the two approaches that they would cover in their own research. The first approach was defined as the local-to-global approach, meaning the placement and distribution of plant densities was controlled by simulations of interactions between individual plants. The second approach, global-to-local, was distinguished as controlling plant positions by inferring from large-scale density distributions.

Based on Jane and Prusinkiewicz (2002) analysis of procedural plant placement, they suggested a system that placed plants randomly in a virtual environment and iteratively 'grew' them, and 'killed' them when dominated by larger plants. "The resulting distribution fit the self-thinning curve of plant ecology, a relationship between the average mass and average density in a monoculture of plants of the same age." (Lane & Prusinkiewicz, 2002). This 'growth & death' system was developed further to implement the previously mentioned local-to-global approach. To implement the other proposed approach, global-to-local, Lane and Prusinkiewicz employed the Floyd-Steinberg error diffusion algorithm alongside a singular grayscale image to create each individual plant position.

While both local-to-global and global-to-local systems were fine in terms of placing arbitrary points in a random yet controlled manner, they both lacked something apparent in real-world ecosystems, clustering. Lane & Prusinkiewicz, (2002) define clustering, also known as clumping or under dispersion, as "a common phenomenon, caused by environmental factors (plants of the same type tend to cluster in the areas favourable to their growth), propagation (seeds fall close to their parent plants, or plants propagate by runners), as well as other mechanisms."

They state that clustering has a significant impact on the appearance of any plant distribution, causing their interest into modelling it. To simulate this phenomenon, Lane and Prusinkiewicz (2002) utilized the Hopkins Index, which is an algorithm that calculates the ratio of the distance from a tree to its nearest neighbour, as well as the distance from random points within the same space as that neighbouring tree as shown in the following equation. (Lane & Prusinkiewicz, 2002; Natural Resource Biometrics, 2014)

$$H = \frac{\langle min_i(\|x - p_i\|)\rangle x}{\langle min_i(\|p_j - p_i\|)\rangle j}.$$

In the above equation, the value H is cluster tendency. A value of H close to 1 tends to indicate the data is highly clustered, and uniformly distributed data will tend to result in values of H close to 0. The value x is the desired distance between points. Value p_i is the initial point being used in the distance calculation and p_j is a random point near p_i.

Plant Ecosystem Modelling and Rendering

Oliver Deussen, Pat Hanrahan, Bernd Lintermann, Radomír Měch, Matt Pharr and Przemyslaw Prusinkiewicz have produced a study into the best method for modelling and rendering a realistic plant ecosystem. Duessen et al. have listed the five main techniques they used to design and implement the plant ecosystem, these techniques are; A multilevel modelling and rendering pipeline, open system architecture, procedural models, approximate instancing and efficient rendering.

A multilevel modelling and rendering pipeline was used to divide the system Duessen et al. produced. This was useful as it allowed the user to focus on one segment of the system without worrying about how it will affect the others. "Thus, the modeler is not concerned with plant distribution when specifying the terrain, and plant distribution is determined (interactively or algorithmically) without considering details of the individual plants" (Duessen et al., 1998).

An open system architecture was implemented in the project, allowing for the incorporation of independent modules. These modules would be able to affect any part of the system, thus allowing for easy implementation of new plant models, different placement methods and generation approaches.

Procedural models are usually defined by substantial data-base amplification, meaning they can create and generate complicated geometric structures from a small amount of inputted data. Duessen et al. (1998) stated "We benefit from this phenomenon by employing procedural models in all stages of the modelling pipeline."

Approximate instancing, a combination of object instancing and approximated clustering, was incorporated into the project as the main method for reducing the end file size of any rendered scenes. To optimize the amount of instancing, objects and their components were clustered in their parameter space.

After this approximated clustering, objects within any given cluster was rendered with instances of a singular representative object. Duessen et al. (1998) extended this system by "applying vector quantization to find the representative objects in multidimensional parameter spaces."

Finally, Duessen et al. used memory and time efficient rendering techniques to speed up to time it took to render their generated scenes. These techniques included: the dissection of the generated scene into sub-scenes for composition in later steps, ray-tracing with instancing support for rendering many polygons and memory-coherent ray tracing applicable to instanced objects.

By applying these techniques to their project, Duessen et al. generated and rendered a scene that held up to 100,000 highly detailed objects. This number could be further increased, however Duessen et al. (1998) stated that "with 100,000 plants, each plant is visible on average only in 10 pixels of a 1K x 1K image. Consequently, we seem to have reached the limits of useful scene complexity, because the level of visible detail is curbed by the size and resolution of the output device."

This literature review identifies that while many contemporary content generation algorithms and techniques can create large, immersive and intricate environments, they are rarely designed and optimized to run in real-time. As such, this research aims to create and implement of content generation algorithms that can generate and simulate immersive virtual forests in real-time.

To achieve our goal, this research incorporated seven different systems: Height Generation, Terrain Texture Generation, Detail Generation, Point Generation, Shadow Map Generation, Life Cycle Simulation and Day/Night Simulation. Through the combination of these systems, this research provided a unique method of fully generating and simulating a virtual forest environment in real-time.

Generating a Virtual Forest Environment

One major constraint in simulating an entire virtual forest environment lies in the substantial amounts of objects that need to be rendered on screen at once. This issue is further amplified by the fact that the virtual forest this project will be generating needs to be rendered 60 times a second. Each of these renders are referred to as 'frames', and the rate at which these frames are updated is called 'Frames Per Second' (FPS). This project intends to render the generated virtual forest environment at a minimum of 60 FPS.

In contemporary Video Game Engines (VGEs), each rendered frame is broken down into 'draw calls'. These draw calls refer to any object that needs to be 'drawn' on each frame; the more objects drawn, the slower it takes to render a frame. In addition to draw calls, the FPS of a project can also be negatively affected by un-optimized scripts. To increase the FPS of a project, there are a few techniques that can be employed within VGE. These include, but are not limited to, Graphics Processing Unit(GPU) Instancing, Occlusion Culling and Garbage Collection(GC) optimization.

The first technique this project implemented was GPU Instancing, which rendered multiple copies of a mesh simultaneously, thus reducing the amount of draw calls needed. The main usage of GPU instancing is when multiple copies of the same mesh are placed throughout the scene, making it a viable option for a forest environment as they tend to be filled with a few dominant plant species.

The second technique this project used was Occlusion Culling, a technique that deactivates any mesh that is not visible to the camera. An example of occlusion culling is if the camera is close to a tree in the scene, any meshes behind that tree are deactivated, as the camera wouldn't be able to see them anyway, thus decreasing the amount of draw calls needed to render the scene (Figure 1).

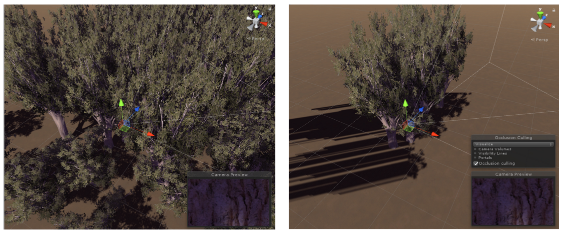


Figure 1. An example of occlusion culling. Left: No occlusion culling. Right: Full occlusion culling

GC optimization was the third technique for increasing the project's FPS. Garbage, in terms of VGEs, is the term used for memory that has been set aside to store data, but is no longer being used. Garbage Collection is a process that cycles through the allocated memory and frees up unused memory for other tasks.

Height Generation

Generating and customizing terrain heights in contemporary VGEs are usually done using heightmap textures. The VGE interprets the heightmap texture given to it to change the height of the terrain based on the colour of each pixel on the texture. To generate a completely new texture to feed into a VGE terrain (hereby referenced to as Terrain), one of the obvious options was a simplex noise texture. A simplex noise texture is a texture that consists of randomly placed black and white pixels. This however, would not create a realistic environment as it lacks any correlation between pixels that was needed to simulate gradual hills and valleys.

So, noise textures were the solution, but simplex noise was too cluttered and erratic to create a convincing environment. A solution to this was the use of a different type of noise; Perlin noise. Perlin noise is a type of 'gradient noise', created by Ken Perlin in 1983.

Terrain Texture Generation

In this project, certain textures were needed to be applied to the Terrain based on different 'rules' that were defined through development. These rules included; "only place rock textures on steep cliff sides" or "only place grass textures on low, flat plains".

The first rule implemented was how exactly to place the grass textures, this was important as forest environments have plenty of lush grass within them. Both the height and steepness of each pixel in the Terrain heightmap were used to implement this 'grass rule', as it was desired for grass to primarily grow on flat terrain at lower altitudes. The flatness portion of the rule was more complex than the height portion, as the GetSteepness function returns a value that isn't 'normalised', normalised meaning it is not a value between 0 and 1. Another hurdle was feeding the pixel's height into the algorithm in a way that allows for smooth transitions between grass being placed and grass being ignored. The algorithm developed to calculate this grass rule was as follows:

$$x = clamp(\cosh \llbracket g/h \rrbracket - 1.25) - clamp((s * s)/(t/f))$$

Where x is grass texture transparency from 0 – 1; g is grass height lenience; h is height of the current pixel; s is steepness of the current pixel; t is the max height of the Terrain; f is grass flatness lenience

This algorithm returns the value *x* as the 'weight' of the grass texture from 0 to 1, with 0 meaning grass with full transparency (thereby invisible) and 1 meaning grass with no transparency (fully visible). This 0 to 1 value was necessary for blending between different textures on the Terrain. The *g* variable in the algorithm was the grass height lenience; this variable controls the altitude at which grass can grow. The *f* variable pertains to how flat the pixel must be to be considered for grass placement. The lower the *f* variable, the steeper the pixel can be before being rejected by the grass rule.

After developing and integrating the grass rule into the Terrain Texture Generation system, the next rule to develop was the ‘rock’ rule. This rule defined where exactly rock textures should be placed on the Terrain to increase variation and detail. These rock textures were to be placed on high and steep sections of the Terrain to simulate mountainous regions. Like the grass rule, both the height and angle of each pixel were inputted into the rock rule, except this rule used the ‘normal’ of each pixel to calculate its angle. A pixel’s normal refers to its rotation value on all three axes (x, y and z). The algorithm used to determine where the rock textures were placed was as follows:

$$x = clamp((h/r\text{^}2) * \cosh \llbracket n/a \rrbracket)$$

Where x is rock texture transparency from 0 – 1; h is the height of the current pixel; r is the rock height lenience; n is the current pixel’s normal value on the z axis; a is the rock angle lenience

Like the grass rule algorithm, this algorithm returned the value *x* as the transparency of the rock texture from 0 to 1. The *r* variable refers to the rock height lenience and was used to make sure the rock texture was only placed at high altitudes. The *n* variable was the current pixel’s normal value on the z axis which makes sure the rock texture was only placed on very steep inclines. Variable *a* referred to the rock angle lenience and was used to control how steep of an incline the pixel needs to be before it gets assigned as a rock texture.

Detail Generation

The next step taken in creating an immersive forest environment was detail generation. Details on a Terrain refer to small ‘details’ such as grass, flowers and smaller plants, thus they were a necessary addition. To generate these details in an optimal manner, the Terrain textures generated in the Terrain Texture Generation system were used. This system could simply reference the texture on each pixel of the terrain and use that data to decide exactly what detail needs to be placed there.

For this texture referencing to work, the Detail Generation system needed to be able to calculate the alpha of each texture it sampled, as the Terrain textures previously generated smoothly transitioned between each other. Once this alpha value was retrieved, it was a simple matter of comparing it against the alpha values of any other textures that could appear on that pixel. After getting the texture with the highest alpha value, the Detail Generation system could finally decide on what should be placed on that pixel.

Point Generation

After developing techniques to control the look of the Terrain itself, this section will be covering the placement of objects upon it. To do this, a technique that was investigated in the previous section, Poisson Disc Sampling, was implemented. This technique essentially made sure that each object was placed a certain distance away from any neighbouring object. By implementing this technique, a random, yet uniform distribution of objects across the Terrain was achieved.

In this project, specific objects needed to be placed on specific parts of the Terrain. To do this, it was required to analyse the texture beneath each placed point before deciding whether it should be placed there or not. This selective placement allowed for better control over the look of the forest environment.

Shadow Map Generation

After the system that placed the initial objects throughout the scene was created, a context-sensitive object placement system could be developed. The context this system focused on was light level, or how bright or dark each section of the Terrain was. This was ignored in the previous section as there was nothing in the scene to cast any shadows.

To properly evaluate the shadows within the scene, a *shadow map* must be created. A shadow map is a black and white texture that illustrates both the size and position of all shadows in the scene. After generating this shadow map, it was then overlayed on top of the Terrain to find exactly where each shadow was.

Generating the shadow map took place in two steps: Render Toggling and Render Texture Output. These two steps allowed the system to have direct control over exactly how and when the shadow map was generated. These steps, in conjunction with a single orthographic camera, allowed the visualization of all the shadows in the scene.

The first step, Render Toggling, retrieved all the objects placed through the Point Generation system and toggled the renderer of each object for one frame. This step was used to ensure the orthographic camera would only see the shadows cast by the objects and not the objects themselves. Since this all happened in a single frame, it was not visible to the user as the project was running at 60 FPS.

The second step was Render Texture Output which controlled the orthographic camera and its relevant outputs. This step took place once all the renderers in the scene had been toggled off by the Render Toggling step. It turned the orthographic camera on and then assigned a custom ‘shadows only’ shader that made the camera render in black and white, with black being shadows and white being no shadows. The camera then assigned what it rendered to an output texture called a Render Texture.

After assigning the Render Texture, it had to be converted to a normal image texture for evaluation. This was a simple matter of reading and transferring all the colour data from the Render Texture to the new image texture. Once the colour data had been transferred to the image texture, the system cleared the Render Texture, so it could be used in later shadow map passes.

Life Cycle Simulation

With the all the necessary objects placed, this section will be covering the system that controlled the simulation of their life cycles. This system controlled how and when a plant in the virtual environment should grow. There was two ‘modes’ for any object that was simulating their life cycle: *Stepped Aging* and *Smoothed Aging*.

Stepped Aging was the mode that took the least amount of resources as it only updated the age of an object in steps. These steps could occur once every five to ten seconds and significantly improved the performance of the scene. Smoothed Aging was the opposite of Stepped Aging, it took more resources but gave the user a better experience as they saw the object smoothly age over time. This mode updated the objects age once every frame, giving it a very smooth transition between young and old.

To properly use both modes, the Life Cycle Simulation system checked all objects that were currently aging within a radius around the main camera. If an object was within the radius, it would use Smoothed Aging, thus improving user immersion. If an object was outside the radius, it would use Stepped Aging instead, thus improving the performance of the scene without impacting user immersion. These two modes were crucial in making sure this system was optimized for a real-time scene, as having hundreds of objects updating their age at once would have an adverse effect on the projects FPS.

Day/Night Simulation

The final system implemented in this project was the Day/Night Simulation system. This system would allow for a more immersive user experience and would make the forest environment less static. The two main conditions this system needed to consider were the lighting and overall colour of the scene. For example, simply having the sun set without changing the colour of the atmosphere would not create a believable sunset.

Firstly, the technique for moving and rotating the celestial bodies, the sun and moon, in the scene was developed. Some considerations were put in place for the key times of day to be realistic. Examples like having midday lasting longer and casting a harsher light on the environment compared to sunrise and sunset had to be accounted for.

The used method of calculating the exact angle the sun needed to be at was to calculate the *solar hour angle.* The solar hour angle is a way of telling the time of day by looking at the angle of the sun in comparison to the horizon. By reversing this technique, this system instead calculated the angle of the sun based on the current time of day.

This technique required the use of *decimal hours*, which is a type of time structure. A decimal hour is the combination of the standard 24hr time structure with the addition of a decimal calculation for minutes. For example, 3:30am (03:30 in 24hr time) will convert into 3.5 and 3:15pm (15:15 in 24hr time) will convert into 15.25.

After calculating the wanted decimal hour, the system used the following algorithm to calculate the angle of the sun from the time of day:

$$s = (360/24) * (d - 12)$$

Where s is the solar hour angle; d is the current decimal hour

In the above algorithm, 360 degrees was divided by 24 to calculate the angle of a single hour. The decimal hour was subtracted by 12 as the angle of the sun at sunrise is -90 degrees, while its angle at sunset is +90 degrees. By taking the hour angle and applying it to the decimal time, the system could accurately identify the angle at which the sun should be. After calculating the needed angle of the sun, the angle of both sunset and sunrise were also calculated. These two angles were needed as specific things needed to occur at those times. To calculate them both, two variables needed to be accounted for, latitude and declination.

Latitude was needed to simulate a geographical position for the purposes of finding the horizon. Declination was like latitude, but was used to simulate an astronomic position instead. While, generally, a point's declination is almost always within 0.01 degrees of its latitude, it was still useful for calculating the exact angles of celestial bodies.

With both latitude and declination accounted for the system could calculate the angle of both sunset and sunrise using the following algorithm:

$$ss = \operatorname{acos} \llbracket -\tan d * \tan l \rrbracket$$

$$sr = -ss$$

Where ss is the sunset angle; sr is the sunrise angle; d is the current declination; l is the current latitude

The algorithm above calculated the angle of the sunset by finding the arc cosine of the negative tangent of the declination times the tangent of the latitude. Once the angle of sunset was retrieved, thy system simply used its negative value to find the angle of sunrise.

Experiments and Results

The implementation of all the aforementioned systems resulted in an immersive virtual forest environment that was simulated in real-time. This section will cover the implementation of each system in the same order as they were discussed in the previous section.

The first system that was implemented was the Height Generation system. This system first needed to generate a perlin noise texture using Ken Perlin's perlin noise generation algorithm. After taking this perlin noise texture and implementing it into a VGE's terrain system, the system could create more believable landscape features such as hills and valleys.

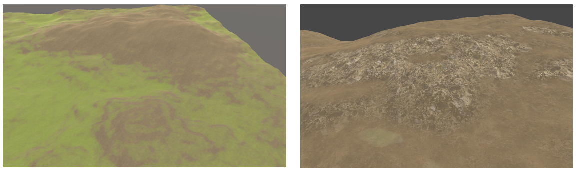
Because this heightmap was generated when the program runs, the system could not feed the Terrain the heightmap texture directly beforehand. To get around this, the system needed to iterate through each pixel on the generated texture and assign their colour value to the Terrain's heightmap. This texture generation continued to create more visually distinct and diverse environments by layering these perlin textures over each other.

This layering of perlin noise textures was useful for adding more features to the Terrain. These features could range from giant mountains to shallow ponds. To layer another perlin texture on top of the existing one, all the system had to do was add the colour data of each pixel in each texture together.

After generating the heights of the Terrain, the next step was to generate a texture to be placed onto it. This texture differed from the heightmap texture generated previously as this texture would be the colour and literal 'texture' of the Terrain itself. Terrains in contemporary VGEs can be painted using multiple different textures, so they must be sectioned off from each other to prevent unwanted blending. To do this, most VGEs partition each texture stored in the Terrain into separate layers. Combining the texture, its position on the terrain and the layer it is placed on results in the Terrain variable, alphamaps.

Changing this alphamap variable requires consideration for all the values it holds; the texture itself, the position at which the texture should be placed and the layer on which the texture will be assigned to. To streamline this process as much as possible, the system assigned most of these variables in the Terrain component itself. Both the texture and the layer value in alphamaps were both automatically assigned when inputting the texture into the Terrains manual texture painting system. After inputting the texture into the Terrain component, all the system needed to do was assign that texture to specific positions on the Terrain itself.

To retrieve the data that the previously developed Grass and Rock rules would use, it was a simple matter of cycling through each pixel of the Terrain's height map and retrieving the height and steepness of each of them. The system used two functions to retrieve this data, GetHeight and GetSteepness. The GetHeight function returned the height of a specific pixel on the Terrain by supplying it with an *x* and *y* value and GetSteepness used those same values while returning the angle of the pixel. By feeding all the relevant information into the Grass (Figure 2-a) and Rock (Figure 2-b) rules, the system gave the Terrain colour and life-like textures.



(a) **(b)**

Figure 2. Implementation of the grass rule and Implementation of the rock rule

With the Terrain Texture Generation system implemented, the next system to implement was the Detail Generation system. To better optimise this system for real-time performance, a variable that controlled the overall amount of details placed on the Terrain named 'DetailPlacementPower' was created. This variable was used just before the Detail Generation system attempted to place a detail on the Terrain. If the detail's position in the Terrain's detail list was a power of DetailPlacementPower it could be placed, otherwise the Detail Generation system would skip over it (Figure 3).

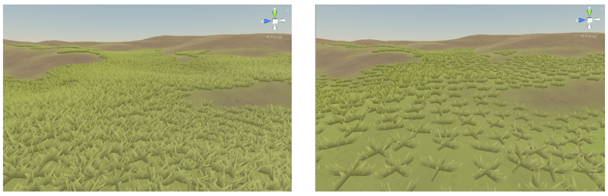


Figure 3. Left: DetailPlacementPower = 1. Right: DetailPlacementPower = 2.

A variable that did the opposite of the DetailPlacementPower variable was also created to control exactly how many details should be placed per pixel on the Terrain. This variable was named 'DetailsPerPixel' and was used to increase the density of the generated details at the cost of performance. The Detail Generation system used this DetailsPerPixel variable when it decided a detail could be placed (Figure 4).

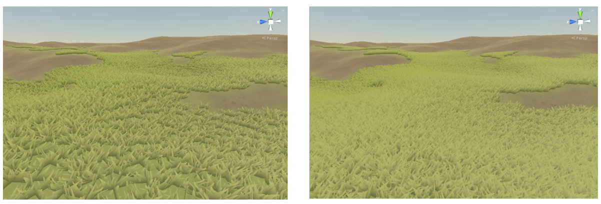
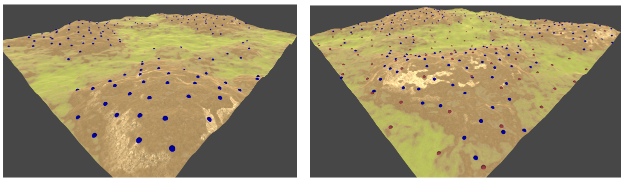


Figure 4. Left: DetailsPerPixel = 1. Right: DetailsPerPixel = 4.

Next up was the Point Generation system that implemented Poisson Disc sampling to place points around the environment. By creating a class called T_Point to store the point's *x, y* and *z* position values, the system could accurately assign each point's position on the Terrain. One issue with the Poisson Disc sampling techniques was that it only calculated positions in a 2D space, meaning the objects will be placed at the same height regardless of the actual height of the Terrain. To solve this issue, the system used the previously developed GetHeight function and fed that value into the T_Point class.

With the basic functionality of the Poisson Disc sampling method implemented, it was then possible to implement rules, like those used in the Texture Generation system, to change how these points were placed. The first rule of the Point Generation system that was implemented was a rule to determine where trees should be placed. It was desired that this rule would only allow trees to be placed on dirt, allowing open grass plains to occur. To do this, the same method used in the Detail Generation system that sampled the texture beneath each point was used (Figure 5-a).

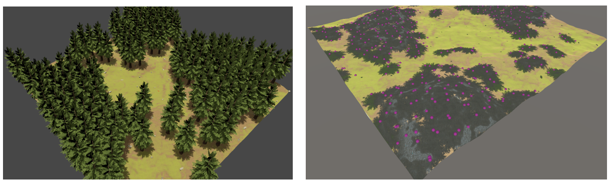


(a) **(b)**

Figure 5. Poisson Disc sampling using the tree rule and Placing the rock points (Blue: Trees, Red: Rocks)

With these points placed via the tree rule, the system then performed another Poisson Disc sampling pass to place rock points around the Terrain. Because of the way Poisson Disc sampling works, it was necessary to separate these new rock points from the previously placed tree points. This was due to the need for rocks to be able to be placed close to trees on the Terrain and merging the rock points with the tree points would make sure they will stay a certain distance away. Since the rocks being placed were not very large or obstructive, it was desirable for them to be placed throughout the scene no matter the height, steepness or texture beneath them (Figure 5-b).

With two sets of points placed throughout the scene, the system could now replace them with actual objects. To do this, the system needed a reference to the object wanted to be placed at any point. Since the position of these points were stored previously, placing objects was a simple matter of iterating through them all and assigning the relevant object at their position (Figure 6-a).



(a) **(b)**

Figure 6. Placing objects on the generated points and Using the Point Generation system to place points in shadow

After placing these objects around the Terrain, it was possible to move on to implementing the Shadow Map Generation system. This system would control how light level should affect the placement of different objects around the environment.

After implementing the Shadow Map Generation technique, what was left was a shadow map texture that displayed all the shadows in the scene. With this shadow map texture created, the system could now evaluate and place objects around the terrain by injecting the shadow map texture into the Point Generation system. It worked quite similarly to the tree rule within the Point Generation system, but instead of evaluating the textures on the Terrain, it evaluated the pixels on the shadow map (Figure 6-b).

With contextual placement implemented, the next system to be implemented was the Life Cycle Simulation system. This system controlled the life cycle of all the trees and plants within the forest environment. To begin implementation, each of the trees placed by the Point Generation system were assigned a component called a *Life Cycle(LC) User*. This component controlled variables such as the speed at which each tree would age, how old it could be and how quickly it should reach maturity.

These LC Users grew on their own, using the previously stated variables to simulate their own life cycles independently. However, when hundreds of LC Users were calculating their life cycles independently, it had a significant adverse effect on the project's FPS. To alleviate the FPS strain, the system used a single manager class to control every LC User in the scene. This class was called the *LC Manager* and would send out alerts and events whenever necessary to all LC Users in the scene. The LC Manager would send certain events to all the LC Users in the scene to tell them when to update their own life cycles. These events occurred about once every five seconds, thus massively decreasing the amount of times the LC Users need to update. This technique of sending events to notify when the LC Users need to age was referred to as *Stepped Aging*. With each tree's life cycle now simulated, it needed to be visually apparent they were growing. This was controlled by assigning a new component to each LC User, the *LC Scaler.* The LC Scaler was a child component to the LC User and was reliant on the life cycle variables within it. The LC Scaler had its own internal variables that control it's minimum and maximum size and the speed at which it would grow (Figure 7).

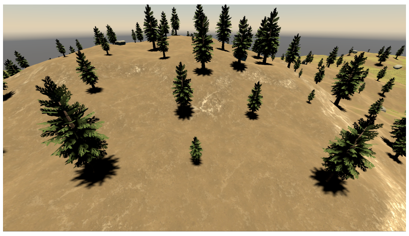


Figure 7. Trees growing using the LC Scaler component

The final system that needed to be implemented was the Day/Night Simulation system. This system would simulate the movement of the two major celestial bodies, the sun and the moon. As the algorithms needed to accurately calculate the sun's rotation at any time of day had already been developed, all that was needed was the simulation of the time of day.

Simulating the time of day was simple, the system just needed variables for *seconds*, *minutes, hours* and *days.* By iterating the seconds value by 1 every second, it was possible to accurately simulate time of day. Once that seconds variable reached 60, the system increased the minutes value by 1 and reset the seconds value to 0, before repeating this step for minutes and hours.

With the time of day simulated, the system could now covert it into decimal hours. The hour value of a decimal hour was simply the hour value in 24hr time, while the decimal value (minutes) required some calculation. Finding the percentage of the minutes variable was as simple as dividing the current minutes value by 60, giving a decimal value between 0 and 1.

There was one issue with just using minutes for the decimal hour however, as it would only update the decimal hour once per minute. This would result in small 'jumps' in the simulation as the sun's angle moves rigidly with the update of the decimal hour. To combat this, the system needed to incorporate the seconds value in the decimal hour as well.

To properly integrate the seconds value into the decimal hour, it needed to be divided by 6000 before adding it into the decimal hour. The reason for dividing it by such a high value was because it was intended for the seconds value to only affect the decimal hour's third and fourth decimal place.

For example, if the time of day was 06:30 and the seconds value was at 35, the resulting decimal hour value will be 6.5058. By doing this, it was possible to have a smooth transition between minutes in the decimal hour. With the decimal hour fully implemented, the system could now use the sun hour angle algorithm and calculate the angle of the sun. Before using the previously calculated sun angle, the way the sun should rotate needed to be set up. To do this, a 'dummy' object in the centre of the Terrain was created before making the sun and moon children of it. By positioning the celestial bodies as children of this dummy object, the system could simply rotate the dummy to simulate the spherical rotation of the sun and moon.

With the celestial bodies rotating, the system then needed to calculate the angles of sunset and sunrise. In this project, the latitude of the Tropic of Capricorn and a declination value of 25 were used when calculating these angles. By using these values and applying them to the previously discussed sunset and sunrise algorithm, the system was left with 1.357 degrees for sunset and -1.357 for sunrise.

After finding these values, the system could now control the overall look of both sunset and sunrise. To do this, the system evaluated a gradient to find the colour it needed. This gradient was evaluated by using a 0 to 1 value, with 0 being the leftmost side of the gradient and 1 being the rightmost side of the gradient.

To retrieve this 0 to 1 value, the system used the following formula:

$$x = (y + (i - r))/(j + s)$$

Where x is the gradient value from 0 to 1; y is the current sun hour angle; i is the minimum value for sunrise; j is the maximum value for sunset; r is the angle of sunrise; s is the angle of sunset

In the above algorithm, a value from 0 to 1 was retrieved by evaluating the current sun hour angle. The value i in this case was 90, as sunrise occurred when the sun hour angle was -90 degrees. By subtracting the sunrise angle from i, the system was left with the exact angle at which the sun would rise past the horizon. The value j in this case was 180 because the sunset would occur at +90 degrees. It then added the angle of sunset to j to retrieve the exact angle at which the sun would set behind the horizon. The system could now take the evaluated colour of the gradient and apply it to the sun to change the look of the environment at sunrise and sunset (Figure 8).

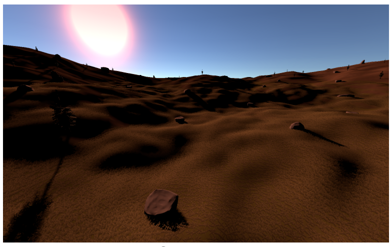


Figure 8 The colour of the environment at sunset.

The system could also simply reverse the gradient algorithm and create a new gradient to simulate the colours of night, from twilight to midnight. Since night is generally shorter than day, it could calculate the leftover decimal hours from the sun angle algorithm to calculate this gradient colour.

Conclusion

As has been established throughout this study, generating a virtual forest environment for real-time requires many in-depth considerations to achieve a realistic and immersive result. Through the investigation, development and implementation of seven unique systems, we have successfully generated a realistic virtual environment that is simulated in real-time. Within these systems, multiple unique algorithms have been developed to improve both the realism and optimization of the final environment.

From the generation of the geographical appearance of the environment, to the simulation of day and night, we have always taken optimizations for real-time into account. This has left us with a virtual forest environment that can be used in many different real-time applications, from video games to simulations (Figure 9).

Other research problems exposed by our development of this system include: (i) improvement on the realistic simulations by simulating rain-fall, seasons, moon cycles and wind; (ii) improvement on the geographical generation by generating rivers, lakes and ponds that would add more distinct features to the environment; and (iii) improvement on the placement system by considering the water content of the soil and the dominant plant species of the environment.

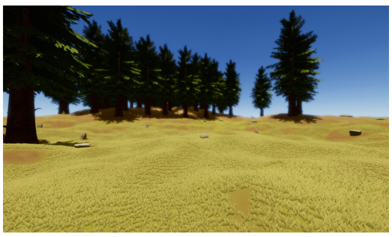


Figure 9. The generated virtual forest environment

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Exploring the Craft of Immersion in Virtual Reality

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Abstract
Virtual reality (VR) systems are increasingly utilised as a medium in which to experience video games. These systems incorporate technology that is designed to offer the user an experience of a simulated physical presence within a virtual environment. The acceptance of VR as a platform for gaming has given rise to many new challenges for designers of games. These new challenges represent a disruption in the craft of game design on a scale not experienced since the transition from 2D to 3D graphics. This paper offers insight into the challenges for designers of VR games through the examination of existing strategies and design principles. These principles are then applied to the construction of a creative work that further expounds techniques for practitioners creating VR games.

Keywords
Virtual reality, game design, video game environment

Introduction
Virtual reality offers new ways of interacting with computers and is applied in fields such as therapy, training and gaming [1]. This is achieved by placing the user in an immersive virtual environment. The field of design for these virtual environments including the ways in which we interact with them is still in its infancy, and as a result, there are many new design challenges to explore. While creative disciplines such as animation have principles established in the 1930's by Walt Disney Studios to guide them [2], creators of VR experiences have little by which to guide practice. This paper reports on a research project that investigates principles of immersion as a key component of design and explores new and emerging understandings of these principles through the creation of a VR environment.

Methods
This study was conducted through a process of practice-led research in which Linda Candy [3] describes "The main focus of the research is to advance knowledge about practice, or to advance knowledge within practice." This method aligns with action research in which new knowledge is created through practice and as a result change of practice may occur. In this particular study, Schön's reflective framework [4] was adopted in which the researcher reflects in and on action in order to generate new knowledge. Reflection-in-action involves interpreting information during the time of the experience. Reflection-on-action involves taking a step back and examining the information as a whole after the experience. Specifically, the research project consisted of four stages which were repeated three times to refine the project and allow for the collection of data. During the planning phase of each cycle, a VR experience incorporating existing design principles was created and revisited. This was in the form of a digital environment using a HTC Vive VR system. Phase two, the acting phase, involved building the environment in Unreal Engine. Phase three, observation, involved being present in the VR environment. The last phase, reflecting, involved a written reflective analysis and planning for the next cycle. Cycles one and two were used to refine the environment with cycle three being used to reach a conclusion. Research data informing this paper is derived from researcher notes made during these phases.

Virtual Reality
Immersion
A key component of designing games for VR systems is the notion of immersion. Immersion in video games is thought of as a profound mental involvement that may cause loss of time and self-awareness at its most immersive point [5]. According to Brown and Cairns immersion can be broken up into three levels, with unique characteristics, which measure the depth of immersion. The first level of immersion is engagement. This level requires the user to invest "time, effort, and attention" according to Brown and Cairns [5]. This may be hindered if the user has a pre-existing dislike towards a certain genre. Brown and Cairns [5] found the longer the play session, the more involved the user would become. During that time, effort must be invested by the user in order to learn the controls and rules. Throughout all of this, the video game must hold the user's attention. The deeper the immersive experience, the more time, effort and attention is needed to achieve an end goal. Engrossment follows engagement in the immersion process. Visuals, interesting tasks, and plot all contribute to the user developing an emotional investment in the video game. The invested time, effort and resulting emotions encourage the continuation of play. At this level of immersion, it was observed by Brown and Cairns [4] that users are less aware of self and their surroundings. Finally, if the first two levels are achieved, the user progresses onto total immersion. At this stage, a user may begin to feel a sense of presence. A detachment from reality and a complete loss of self-awareness occurs, and the user feels as though he or she is inhabiting their virtual representation. This final stage

transpires through a mixture of empathy and stimulus of the senses [5].

Establishing Immersion

To achieve an immersive state, a player must be encouraged to forget the physical world they exist in and instead feel as though they are present in the virtual world they have entered. To begin this process, key areas such as field of view (FOV), resolution and latency must be addressed. When attempting to immerse a user in a virtual experience, it is important to ensure the technology is invisible. Firstly, the field of view must match up with what a human would expect to see naturally. Then resolution must be high enough to be convincing with motion-to-photon latency kept to twenty milliseconds or less to avoid disconnect and possible simulation sickness [1]. As soon as any of these factors fail, the user remembers the technology he or she is using, and the immersion will be terminated.

Principles of Immersion in Virtual Reality

A review of contemporary literature including conferences and journals revealed that in 2016 during the Virtual Reality Developers Conference (VRDC) Ben Throop delivered a talk entitled *Four Principles of Building Immersion in Headmaster*. In this presentation, Throop proposed four design principles: being restraint, physicality, plausibility and isolation. He constructed these principles while developing the VR title *Headmaster* [6]. Throop stated that he had “honed in on development principles that strengthen immersion for the player” arguing that these principles could be applied to VR development in order to strengthen player immersion [6]. Although Throop’s proposed principles, act as a good starting point for designers of VR games they are yet to be thoroughly tested. This research project utilised a VR prototype to more thoroughly investigate Throop’s proposed principles of designing an immersive VR game experience.

Creative Work: Gnome Zone

Gnome Zone is a VR environment created as a method to investigate Throop’s proposed four principles of building Immersion. *Gnome Zone* was built to test and explore the implementation of Throop’s principles within a new VR context. The following outlines decisions made in the creation of the work from the designer’s perspective when considering the principles of restraint, physicality, plausibility and isolation.

Restraint

Restraint, the first of Throop’s proposed principles describes current video games as complex in nature and observed that while this may work for non-VR games, it is not a desired element of VR in its current stage [6]. VR as a medium draws from life rather than existing games [6]. In life overcrowded and complex spaces are overwhelming, the same can be said for VR spaces. Throop [6] encouraged simplistic design and stated: “how believable and compelling an experience is, is not proportional to the complexity of a scene.” An example of the principle restraint can be seen during the early development stage of *Headmaster*. Throop’s initial intention was to create a stadium to surround the VR experience. The idea was scrapped, however, when it became apparent that the same result could be achieved by using darkness as a boundary. Lastly, Throop spoke about the use of sparse moments. Between rounds, lights are shut off to switch scenes. It was noted that players would look up and observe the stars while waiting for the next round [6].

When planning the original design of the environment, it was proposed that the backyard where the gameplay would take place would need to be surrounded by many props such as those found in a typical neighbourhood. Upon reflection surrounding the restraint principle, it was decided that a large square of grass would be sufficient. Initial scene tests and preliminary development of mechanics revealed that the scene was lacking in experience. During build two more props such as benches, shrubs and flowerbeds were introduced gradually until a lack of sparse moments was found at which point props were removed to decrease complexity within the scene [Fig. 1].

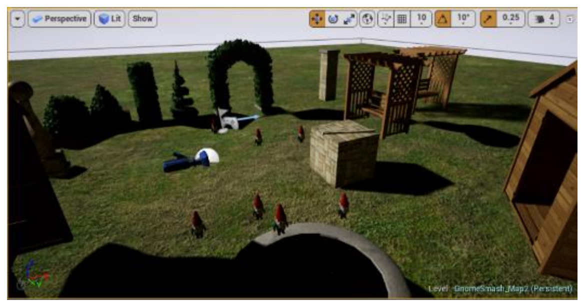

Figure 1, Build Two

The final scene [Fig. 2] included hedges that were intrinsically used to create a border around the yard that also prevented the possibility of seeing past the edges of the scene. A central rectangle with destructible garden objects was arranged while the remainder of the yard had a scattering of trees and grass, and was mostly left open to allow players to easily explore the environment.

Figure 1, Build Three

Physicality

The second principle proposed by Throop is physicality which relates to the physics of the VR world. Throop [6] believes that “base interactions need to be fun as a toy with no game motivation”. In a VR space, it is important to design for the user to be able to interact with anything he or she can reach which means applying physics to everything a user can access. The notion being that physics are not optional as they play a key role in making a VR experience compelling [6]. This principle also encompasses lighting and sound with the suggested standards being real-time lighting and shadows paired with positional audio. In relation to lighting and audio Throop [6] states that “…people have built-in expectations that if not met can break immersion”. *Gnome Zone* allowed for gnomes to be interacted with as they possessed the relevant physics. As a result, players were given the option to pick up the gnome and throw it or hit it with a bat, launching it away [Fig. 3].

Figure 2, VR hand picking up a gnome

During testing, it was realised that by introducing gnomes with real world physics attached, various forms of emergent gameplay, such as throwing gnomes at other garden props were enabled. This was further enhanced with the introduction of a baseball bat allowing users to break the gnome with the bat. This was utilised in a variety of ways such as: hitting the gnome while it lays on the ground, holding the gnome and hitting it with the bat or throwing the gnome in the air and striking it with the bat.

Build two saw further development of the concept of physicality in which it was decided the gnomes should break as they would in the real world. Creating gnomes that were destructible allowed them to shatter upon forceful contact with hard surfaces such as the bat and other gnomes [Fig. 4 and 5]. When considering lighting, it was first decided to utilise the standard system lighting. However, it was found that the light was too bright, and the shadows cast by objects and trees were too dark which had the potential to interfere with a player’s ability to locate gnomes. It was therefore decided that softer shadows and lighting would be beneficial to prolong players’ participation in the game.

Figure 4 and 5, VR hands smashing a gnome

With the positive outcomes experienced by allowing gnomes to be destroyed, the decision was made to ensure that other environmental elements were also able to be destroyed. In the final build garden objects such as benches and flower beds were made destructible [Fig. 6 and 7]. However, allowing a player to destroy a stone flower bed with a wooden baseball bat had the potential to conflict with the plausibility of the world. The design solution for this was to introduce a sledgehammer that could be used specifically with stone objects.

Figure 6 and 7, Bench being smashed by a bat

Although a complete real-time lighting system was not achieved for the latest iteration, environment lighting was refined to prevent interference with player actions. Shadows were lightened while ‘sunlight’ was dimmed. Positional audio was then added to allow players to locate spawned gnomes based on the direction of sound effects. Finally, haptic feedback was introduced to alert the player when picking up an object or hitting an object with the bat. Although not specified by Throop, it was felt that haptic feedback should be considered when designing for physicality and therefore its implementation was explored. In reflection on the principle of physicality, it was found that a majority of the design decisions occurred almost intuitively, suggesting that trained game designers naturally incorporate the notion of physicality in some form. Interestingly it was found that the concept of kinesthetic communication was an important consideration for the project in regard to physicality.

Plausibility

The third principle, plausibility, relates closely to physicality but instead focuses on topical behaviours such as movement within the VR space [6]. Throop described using soccer as a bridge to bring the user into the VR space. Using a familiar concept allows a player to become comfortable in a VR experience which then allows the creator to introduce new concepts that are less aligned with the users understanding of reality. Throop stated that “plausibility is not tied to objective realism” but is instead tied to the rules of the world that are set down within the first moments of the VR experience [6]. To begin investigating the notion of plausibility the elements of the build were considered. The baseball bat prop was the first element to be introduced in build one. It was able to be grasped, swung and thrown, therefore it was considered to be a plausible asset. The next elements to be implemented were the gnomes, which also retained their real-world function and features. Consideration was also given to the environment itself through the introduction of an artificial wind system which gently ruffles trees and bushes. While it was noted that the effects of this were very subtle, the addition of wind helped make the scene more plausible and was noticeable if not present.

Movement within the environment presented many challenges for the principle of plausibility. In order to navigate the environment, the user can only walk within the bounds of her or his real-life space, and therefore other methods are required to traverse the virtual environment. During build three teleportation [Fig. 8] was deemed the most appropriate method of movement due to system constraints. However, when reflecting on the principle of plausibility, this method of movement has potential to break immersion as teleportation does not fit within the backyard theme of *Gnome Zone*. It was concluded that during the design process, strategies for transportation require design solutions that properly employ the plausibility principle.

Figure 8, Teleportation

Isolation

When presenting the principle of isolation, Throop stated that “You need to remember that you’ve got them. There is nothing else competing for their attention in VR by their own choice” [6]. This means that designers have the ability to ask more of a user than would normally be deemed acceptable in video games. Throop used a letter that players read in *Headmaster* as an example. According to Throop, using more than a few lines of text in a screen based games causes players to lose interest [6]. However, in *Headmaster* when players were presented with a letter, they were happy to read it. One player even went so far as to look behind the letter for more information [6]. The principle of isolation illuminated many considerations when building *Gnome Zone*. The research found that isolation was difficult to apply and did not seem to occur intrinsically. It became apparent that actions within the VR environment were not experienced in the same manner as those in traditional games. Using the smashing of gnomes as a task for investigation, it was found that the novelty of the VR experience itself held significance and challenged the principle of isolation. During correspondence with Ben Throop, it was proposed that isolation could also fall under the name “focus” which may better define its use [Throop, personal communication]. Throop proposed an expansion of the original definition by saying “the player's attention is more focused and resilient in VR” [Throop, personal communication]. As a result, the principle of isolation was not applied in its original definition. Using the concept of “focus” an amendment to isolation, elements of realism were introduced. When designing for realism attempts were made to duplicate or mimic actions that would be used in real life. For example, it is common in video games to walk up to a door and press the corresponding button to open the door. In VR however, this need not be the case as users are able to use their hands to perform the turn action to open the door. In *Gnome Zone* players pick up the bat by bending down and grasping the object in VR as seen in figure 9, which couples the action with a real-world movement helping to enhance focus.

Figure 9, Picking up a bat

Designing for realism focus already occurs in VR titles such as *Job Simulator* [7] and has naturally occurred in *Gnome Zone*. In *Job Simulator* [7] every object can be interacted with, and 2D menus are not utilised. *Gnome Zone* conforms to this by allowing the player to navigate the environment and locate weapons instead of using some form of menu to summon them.

Results

Results indicated that while the proposed design principles explored offered important guidance for designers, there were design considerations that did not fit within an established principle. In particular, the study indicated that consideration should be given to aspects of the design that constrain the creator’s ability to follow principles such as

Throop's. These constraints include elements such as hardware and human limitations, which lead to issues associated with render clipping, field of view and fatigue. While technical and physical constraints may initially appear to sit outside of the role of the designer, on reflection, they are revealed to be key components of the design strategies adopted. Constraints as a consideration encourage design decisions to support the chosen hardware and play to its strengths while disguising its weaknesses with modelled features. The concept of constraints also requires the creator to design around human limitations such as fatigue and field of view.

Conclusion

This research project offered valuable insight into current understandings of designing for VR games. Through the identification and investigation of an existing set of proposed design principles for VR, this study has been able to expand upon what was proposed. While knowledge generated from the creative work indicated that plausibility and physicality are essential and almost intrinsic in nature, the notion of restraint did not naturally occur. The last of the proposed principles, isolation was ill-defined. It is recommended that the refined principle of focus be adopted, and consideration be given for realism in motion so that this principle may become an important part of designing for immersion. Finally, constraints has been added as a fifth principle for consideration in order to encompass the notion of design restrictions caused as a result of technology and human limitations which have not been addressed within the four existing principles.

Acknowledgements

Thank you to the staff and students from the Bachelor of Games and Interactive Design at the University of Canberra as well as Ben Throop for his assistance during the research period.

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Approaches to Modular Construction for Real-time Game Environments

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Abstract

Video game design and development has evolved into a profitable and widely accepted creative field that operates with ever-increasing technical capability. This improved capability has facilitated an increase in the visual fidelity achievable within real-time environments. Game artists faced with creating these environments are tasked with maximizing both system resource allocation and efficiency in production time. One strategy that has been adopted by artists is to implement a modular design and construction approach when developing environmental elements. Although this approach offers many benefits for artists, the associated skills and techniques are not well defined. Through an exploration of existing literature and reflection on current practice, this study identifies and evaluates a range of contemporary approaches to modular construction for real-time environments, and in the process, offers valuable insights for practitioners.

Keywords

Video games, Modular, Game Design, 3D, Environments, Real-time

Research Introduction

Introduction

When developing games within real-time engines there is a need to be conscious of the limitations imposed through the computer system's capability to render information. The introduction of strain on the system may cause adverse effects to the gameplay experience and therefore the challenge for the designer of real-time game environments is to create highly optimized worlds that balance the system's performance with aesthetic quality. Designers of games have utilised a variety of strategies in order to optimize performance and manage systems resource allocation. One contemporary approach that has emerged involves the notion of modularity in design. Modular approaches involve breaking a scene into smaller components which are then brought together to make the full scene. Modularity offers improved performance through a reduction in unique draw calls that are initiated within a real-time scene. Designers of video games have adopted a variety of approaches when considering modularity, many of these approaches are not well defined and as a result fall under the umbrella term of 'modular'. As a result, designers attempting to adopt these modular approaches within a variety of contexts have little to guide them. This paper reflects on a practice-led research project that offers valuable insights for practitioners attempting to employ modular approaches within real-time game contexts.

Real-time Graphics

The field of real-time graphics is focused on the production and rendering of computer generated images in real-time using a graphics processing unit (GPU). These images are rendered sequentially as frames to simulate graphical scenes and movement. The speed at which these frames are rendered in seconds is referred to as framerate. Lower framerates caused by the system's inability to process information in a timely manner is generally considered unfavorable, as the simulation of seamless motion is lost. To avoid this, creators of real-time graphics must balance image quality while attempting to minimize resource usage. Real-time graphics can be traced back to the software Sketchpad. Released in 1963, the world's first real-time computer graphics application [3]. The evolution of 3D real-time graphics has enabled the processing of 3D imagery in real-time. These 3D images are constructed using a collection of locations in 3D space that allow for the generation of faces known as polygons, which are connected together in order to create a mesh. Through digital rendering images and textures are applied to the mesh coordinates in order to add surface detail and colour.

Figure 1: A mesh created using polygons [20]

When considering optimization in real-time video game environments, one primary area of concern is mesh complexity. As seen in figure 1, meshes are a collection of polygons created and arranged within 3D software to create an object. When rendering a scene in real-time, the computer system is required to render these meshes in real-time, which can become very hardware intensive, particularly on the graphics and central processing units (GPU and CPU respectively). As a result, real-time design is constrained by the system hardware [3]. Early forms of real-time graphics for video games were limited in the amount of complexity that an object could have and would rely heavily on baked lighting and surface textures to convey meaning. This would limit the amount of visual fidelity that developers could achieve [7]. Since the release of Wolfenstein 3D in 1992, real-time graphics have experienced a steady increase in the visual fidelity for environments [9]. This has been enabled by the development of new computing hardware that is capable of processing an increased number of polygon meshes on screen at a given time whilst displaying higher resolution surface textures [9]. This ability to render more simultaneous objects on screen affords designers the ability to manage system resource allocation through techniques used in asset and scene construction. As a result, contemporary approaches to 3D design for real-time environments emerge within practice. One such approach is the notion of modularity in design [11].

Figure 2: Early Virtual Environments [15]

Modularity in Design

Modularity in design is an approach found in disciplines such as architecture, technology, biology and game development. Uday Farhan describes the modular process as "*assembling a number of fixture elements in a feasible sequence that is properly determined*" [12]. In video 3D real-time environment design for games modularity is applied through the creation of smaller components designed with the intent of being combined for the creation of new assets, props or structures. This form of modular design draws comparisons with the plastic construction toy *Lego* which uses a series of pre-constructed pieces in order to produce a variety of creations. This can be observed in figure 3, where the same window module is applied between multiple buildings, removing the need for additional time in creating several independent models.

Figure 3: Lego Modular Design [20]

This process was adopted due to its ability to lower the development workload and optimize game performance. This is due to the environment artist only needing to create a small series of assets which can be reused by the system, rather than creating unique assets for each location [8]. Modularity can further be broken down into different approaches [18], these two particular approaches will be covered through an analysis of two video game releases, FromSoftware's 'Dark Souls 3' and Creative Assembly's 'Total War: Warhammer'.

Modulation in Games

Modularity in design has been employed in a variety of modern games, each adopting different approaches to constructing their environments. For example, 'Dark Soul 3' utilises a common form of modular design found in contemporary games through the creation of a series of small assets which are combined together to create all architecture found within the game. This approach is explained by Benjamin Roach, a level designer for From Software who states that

> "*As Dark Souls 3's environments are predominantly large and detailed I discovered that modularity and flexibility were key to making the level when it comes to models. There are very few unique models in my entire scene*" [25].

This process reduces the total number of unique models required to be produced and therefore offers improvements in time efficiency for developers. The modules repetitious nature is concealed through the use of foliage and minor model variations [25].

Figure 4: Modular implementation in Dark Souls 3 [25]

While Dark Souls features a large variety of individual modules created in a planar fashion, Creative Assembly make use of a different approach to modularity in design with their PC title 'Total War: Warhammer' [26]. Buildings are assessed and divided into primitive shapes that are collocated in order to create a variety of structures. As shown in figure 5, buildings have been broken down into primitive shapes; these modules can then be applied in a variety of ways to achieve different architectural forms.

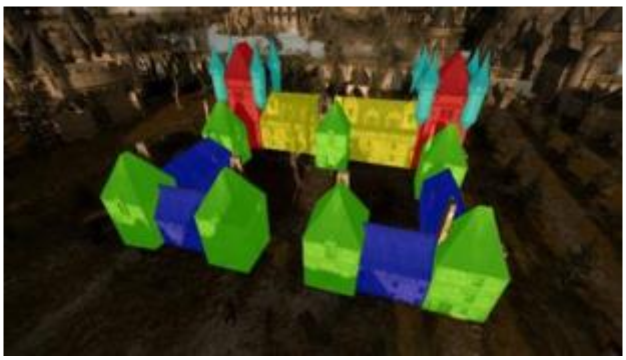

Figure 5: Modular breakdown in Total War: Warhammer [26]

Modularity and the Designer

As can be demonstrated in these two examples modular design for game environments is applied in a variety of forms. Different modular approaches clearly exist; however these approaches are not well defined, with each approach existing within the overarching term of 'modularity'. This brings to light the need for more clarity in distinguishing the variety of approaches for modularity in design [18]. While the environment artist has played a staple role in video game design since the inclusion of 3D graphics, there exists a need to identify the modular practices used by contemporary game development. This paper reflects on a practice-led research project that examines modularity in video game design. In this study three primary approaches to modularity in design for game environments are identified and explored through practical application.

Methodology and Methods

Practice-led research involves utilising methods associated with a qualitative practice, with an emphasis on a reflection based approach. This study adopts a practice-led approach in line with the definition offered by Carole Gray, who states that practice-led research is:

> "Firstly, research which is initiated in practice, where questions, problems, challenges are identified and formed by the needs of practice and practitioners; and secondly, that the research strategy is carried out through practice, using predominantly methodologies and specific methods familiar to us as practitioners." [10]

Through planning, acting, observing and reflecting, this research explored the concept of modularity in design for real-time game environments in order to gain a more thorough understanding of contemporary approaches employed in modular game environment design. This research project was conducted in a three cycle format with each cycle introducing and exploring a different approach the modularity in design. Each cycle was compared and contrasted with the other cycles with the aim of discovering the advantages, disadvantages and appropriate application for each approach. Data informing this paper was collected in the form of a development diary and observations made during practice.

Research Analysis and Findings

Introduction

Through an examination of contemporary games this project identified three specific methods applied in real-time scene construction. Throughout this study these approaches are referred to as the following:

- ***Planar*** method – The designer uses one-sided uniform modules which are snapped together in a 'jigsaw' style.
- ***Box*** method - The designer incorporates larger intersecting assets with each individual asset featuring a higher level of detail.
- ***Diverse*** method - The designer develops a series of non-uniform modules which are designed to interact with every other module in an unconventional manner.

These methods were applied in the creation of scenes that provide insight into system performance, development time and how applicable each approach is to different development contexts. This study addressed planar, box and diverse approaches as previously described, and it should be noted that other modular approaches fall outside of the scope of this project.

Technology

The practical component of this research project utilized the following software: Blender, Adobe Photoshop and Unreal Engine 4. Blender was selected for the creation of assets due to previous development experience and the simplicity associated with in translating methods to other forms of 3D modelling software. Adobe Photoshop was used to edit and create textures for the scenes.

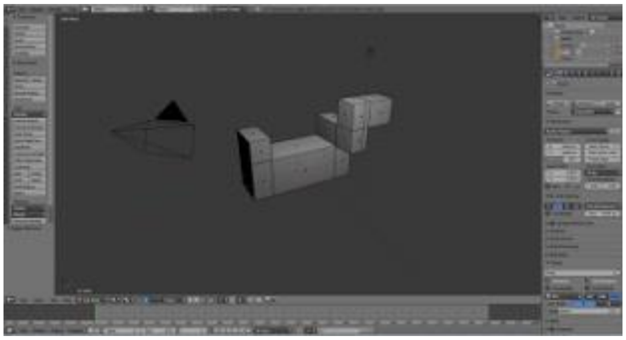

Figure 6: Blenders User Interface [5]

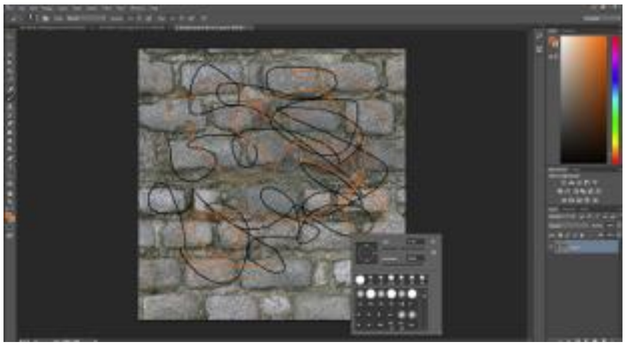

Figure 8: Photoshop User Interface [2]

The scenes were constructed using Unreal Engine 4, as this software is used extensively in contemporary game development. Examples include: Fortnite, Gears of War [8], Absolver [1] and Hellblade: Senua's Sacrifice [30].

Figure 9: Unreal Engine 4 [29]

Practice Cycle 1, Planar Method

One method commonly seen in many games such as XCOM 2, Fallout 4 and Skyrim is the creation of single-sided modules with uniform dimensions that can be implemented in a 'jigsaw' style. For the purpose of this study I will refer to this method as 'Planar' modularity.

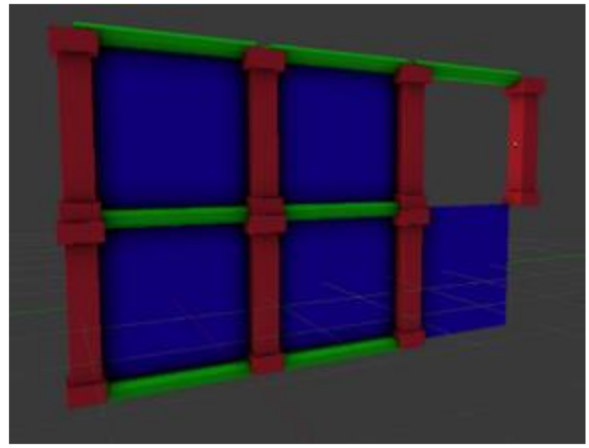

Figure 70: Planar Modular Design

This approach can be observed in games such as 'XCOM 2' [31] which applies this method in a randomized nature. In this context the system randomly generates environments from a series of prefabricated modules.

Figure 81: Planar Modularity in XCOM 2 [31]

The first phase of my project involved exploring planar modularity through the construction of a scene which included the following primary assets:

- Wall module
- Pillar
- Cornice
- Trim module
- Floor module
- Ceiling module

To keep a level of control between each approach, I opted to maintain a similar architectural style between iterations. A medieval design style was chosen due to the modular nature employed in many examples of medieval architecture.

Figure 92: Medieval Architectural Breakdown [28]

As seen in figure 13, the modular nature of medieval architecture was translated into a digital game environment.

Act / Observe

The initial environment was created primarily of small one by one tile modules. These were then complemented by a pillar and cornice object to hide the seams between each planar module.

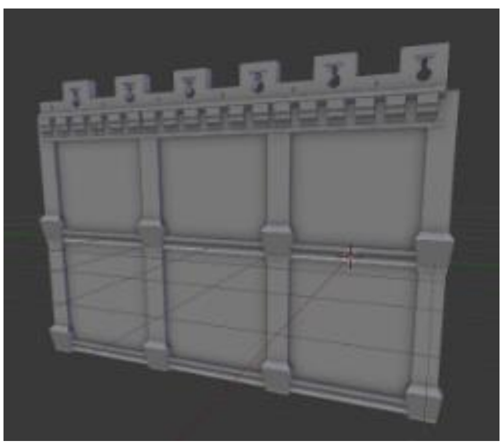

Figure 103: Artefact 1, Basic Modules

These assets were then expanded upon with 'hero' objects, which are unique assets designed to combat art fatigue brought on by monotony. Variations to existing modules were also created for the same purpose. While this may not apply to every module, I did discover that this method was fast to develop and texture due to the simple topology of the individual objects.

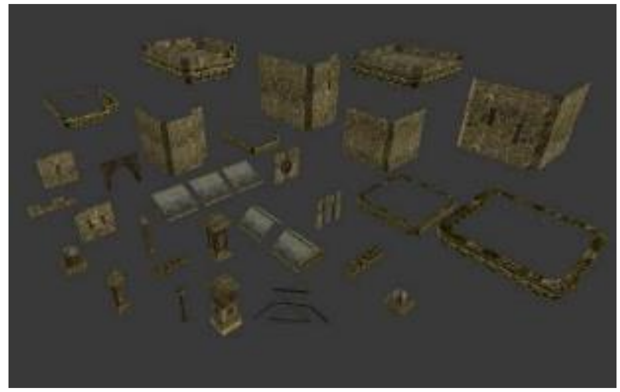

Figure 114: Artifact 1, Completed Modules

For engine implementation and performance testing, a series of vegetation meshes such as bushes, trees and grass, were developed to be utilised between artifacts in order to emulate the performance strain that additional details would contribute to engine performance. Implementation into the game engine was slightly more time consuming than creation, primarily due to the application of level of detail meshes. A major advantage of this modular approach is the ease with which the user can alter individual modules without causing issues with the rest of the 'kit'. Originally it was planned to only feature planar modules within the scene, however during the study it was found that utilising larger assets, particularly in locations further from the cameras, allowed for a reduction in rendering time and offered significant performance advantages.

Figure 125: Artifact 1, Engine Implementation

Although scenes were initially developed one module at a time it was discovered that this approach was incredibly time consuming. Due to the constructed assets consisting primarily of smaller modules, a greater level of control over the scene was offered for the designer. It should be noted that assembling these modules in the scene was also time intensive. Interior sections of the buildings were also difficult to develop as the uniform size of the modules did not account for the pillar assets which lead to the modules being off-center by a small margin with each placement. Consequently, interior scenes usually intersected unnaturally or were not aligned with walls.

Reflection

Planar modularity proved to be an effective way to assemble an environment. The primary issue with this approach was the long development time in-engine. This is due to the smaller size of modules. This could be avoided with the use of prefabs at the risk of losing some of the flexibility provided by the module's design. This work indicated that this process is best used when developing either an interior or smaller environment manually, as the smaller modules allow for greater control over the structure of levels but can also lead to increased construction time in larger scenes, where tiling has potential to negatively impact engine performance.

Practice Cycle 2, Box Method

Another method observed in contemporary games is the use of larger modules which can be used independently and in collaboration with additional modules. This approach can be observed within games such as 'Assassin's Creed: Unity' [4] which consist of larger building modules which can be interchanged with a range of similarly scaled modules in order to create unique architectural designs. For the purpose of this study I will be referring to this practice as 'box' modularity.

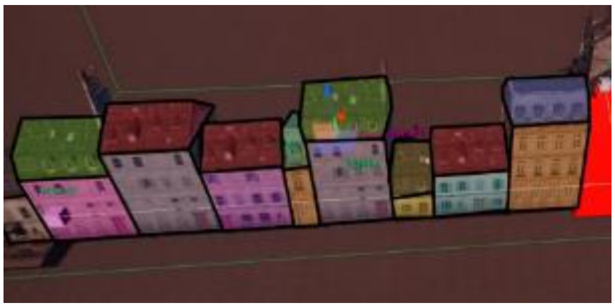

Figure 136: Box Modularity in Assassin's Creed Unity [17]

The second phase of this project involved the development of a real-time scene utilising a box modular approach. This will feature the following primary assets:

- Square building module
- Roofing module
- Pillar module

Act / Observe

The initial assets were developed using a one by one by one uniform scale before complimenting them with a series of pillar and cornice objects to assist in combining elements. The viability of these assets was tested within the chosen 3D software to ensure that they could be used in tandem with one another. The design for this cycle was restrictive in nature when compared to the previous approach with box modules allowing for very little intricate detail in the structure of scenes. This approach did offer advantages in the number of assets required to build the scene in order to achieve the same visual fidelity as cycle one of the study. Level of detail meshes were also more time consuming than the initial cycle due to the added visual fidelity found in these larger meshes.

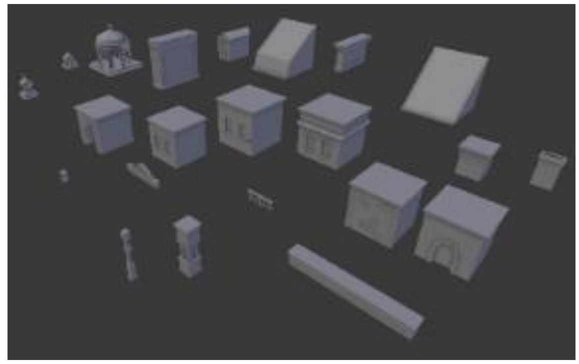

Figure 147: Artifact 2, Individual Box Modules

Assets were imported into Unreal, where they were arranged into a basic game environment. Surprisingly, this approach required almost the same amount of time to assemble an environment as found with the planar method. Restrictions brought on by the asset sizes also had implications for creating variety within the environment. Optimisation was less effective due to the larger module size leading to unseen faces being rendered as well as less culling and level of detail transitions. The primary advantage this practice offered was the ability to create high visual fidelity with a low number of assets. In contrast cycle 1 of the study also required additional time to be dedicated to furnishing these assets in order to avoid art fatigue.

Figure 158: Artifact 2, Engine Implementation

Reflection

After the completion of this cycle the study indicated that the method described as box modularity applies to very niche applications. Games such as Assassin's Creed Unity [17] utilise a procedural generation system alongside this approach, allowing the developers to uniformly scale these assets in order to generate large pieces of the environment through automated systems. In terms of manual placement, the practice was unsuccessful in saving development time and in some places even hindered implementation due to the strict scale and application of the assets. Box modularity offers benefits for optimisation and development time when used in randomly generated or larger exterior scenes where the modules can be used to cover a larger surface area without the need for intricate detail.

Practice Cycle 3, Diverse Method

The third approach explored borrowed elements from both of the previous approaches but applied them in an unconventional manner. This form of modularity features non-uniform modules utilising a variety of scales, which can intersect and be resized allowing for more freeform application of the modules. For the purpose of this study this method will be referred to as 'Diverse' modularity. Research for the study indicated that this approach is utilised throughout contemporary game development, one example examined for this study is the game Bloodborne [6].

Figure 16: Diverse Modularity in Bloodborne [6]

As seen in Figure 21, the building can be broken down into its individual elements, which can then be observed in other buildings within the environment. To help replicate this style, this project borrowed heavily from Bloodborne's [6] design which features the following primary assets:

- Pillar module (multiple variations)
- Roof module
- Window module
- Wall module

Act/ Observe

Phase three began by creating the series of pillar modules, as their extensive use can be observed in figure 19, forming the vast majority of the structure, and is complimented by smaller wall elements. These were then complimented by several unconventional objects which varied in size and surface design.

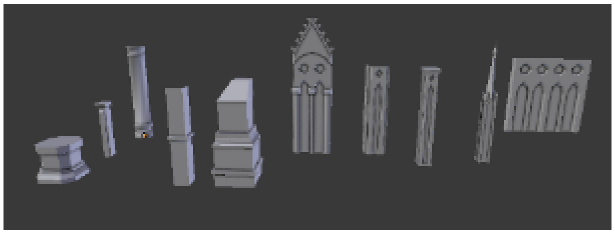

Figure 170: Artifact 3, Sample of Modules

The preparation and development of these assets proved to be the slowest of all the cycles, requiring more time for planning, modelling and texturing. These assets were time consuming to develop due to their non-uniform design, meaning each asset lacked a starting reference or an effective way to test their tileability during development. Breaking down reference images into individual assets was also difficult for these reasons. Implementation into the game engine continued the trend of time consumption, as assets required large periods of time to be devoted to optimization, such as implementing multiple levels of detail in order to counteract the higher number of individual modules present in the scene.

To save time prefabs were created for larger modules which could be used in a style similar to planar modularity.

Figure 181: Artifact 3, Prefab Modules

Interestingly this increased the speed of development dramatically, the larger prefabs allowing for the creation of a variety of building designs in a shorter time than both previous cycles. The smaller size of the individual modules also allows for a larger range of variety in the architecture while maintaining a high level of visual fidelity.

Figure 192: Artifact 3, Prefab Modules Used to Create a Building

Issues associated with this approach include an impact on performance, with the scene experiencing very low framerates when utilizing baked lighting. This meant the scene had to rely on the lower quality dynamic lighting systems.

Figure 203: Artifact 3, Completed Scene

Reflection

The outcome for this cycle was surprisingly successful, providing the most visual fidelity as well as the fastest development time once in-engine. The major setback for this approach is the development time prior to engine implementation, as the creation of individual modules can be very time consuming. Like Planar modularity, this process is best used when developing more confined, linear experiences manually, as the developer can use the linear nature of this approach to better optimise their scene. Larger, more open scenes may experience performance problems due to the density of assets needed to create the prefabs. For this reason, extensive use of level of detail maps or level streaming should be considered when applied in larger scenes.

Results

This research project involved three practice cycles, each of which incorporated a different approach for modular design. These cycles were used to analyze the primary advantages and disadvantages of each approach to practice. Cycles one and three proved to be the most effective strategies for developing within a wider range of contexts and visual fidelity, while cycle two was found to be more specialised in its application. Cycles one and three featured a greater density of assets than that of cycle two, allowing for the individual modules to be applied to a greater variety of situations. The larger density of assets found within cycle three caused performance issues in some circumstances, one of these circumstances being when baked lighting is used within the scene. Further research into optimization processes may be beneficial in identifying ways to resolve this issue. Cycle three also presented a need for further investigation due to the implications that the non-uniform approach to asset creation has on practice.

Research Conclusion

Through the examination of contemporary game development methods this study Identified three primary approaches to modular practice described as Planar, Box and Diverse. Cycles of practice revealed that when applied in the appropriate context all three approaches offer significant advantages in regard to development time and performance efficiency. The study also revealed that some inherent disadvantages may occur between the three methods of practice examined, such as the performance cost associated with the diverse approach or the limited scope of box modularity. These findings indicate that the success of modular approaches is largely dependent upon the development context and the desired effects. Designers considering modular approaches require a clear understanding of the development environment in which they are designing. Factors such as procedural generation and scene type and size may impact the effectiveness of the chosen approach. It is essential for designers when considering modularity for real-time game environments, to apply methods of practice that are congruent with the development context and environment.

In conclusion, this research project has identified three contemporary approaches for modularity in design referred to as planar, box and diverse. Through a practice-led approach this study demonstrated the implications of each contemporary approach for practitioners, offering valuable insight into modularity in design for real-time games. While the insights offered in this study provide a starting point for modularity and practice, further research is needed to advance our understanding of best practice in modular design within the specific contexts of real-time game environments.

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Capturing Willandra

Bringing a Hidden Historical Site to Interactive Digital Life

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ABSTRACT

The Willandra trackways are one of Australias most important historical sites. They include the footprints of our earliest Australians, some 20,000 years old, and all held in what was once a muddy claypan of the Willandra lakes region. The region today is a dry arid area, but 20,000 years ago it was very different, with waterways and a series of lakes (and importantly shallow lakebeds). The footprints embedded in these claypans are a critical piece of Australias human history, but unfortunately these national treasures are hidden, for their own protection, beneath a layer of sand and thus are completely unavailable to the broader public. The potential to utilize digital technologies to capture, and make available to all, this irreplaceable site, and the stories it contains, is significant. Although this offers great potential, there are many challenges in turning a hidden historic site into an enjoyable digital interactive experience that has no negative impact on the sensitive site itself. These issues start with simple access issues, and the basic question of "Can we get access to the site?" is often one of the most challenging elements. Even with good accessibility the technical challenges in safely capturing the site, capturing and understanding the stories it tells, and then converting that into an interactive digital story or experience requires complex technical skillsets and workflows. These workflows are continually being developed as part of this research. This paper discusses the challenges in using digital capture techniques to capture, store and convert this valuable historic data into interactive experience, and the ways that these techniques can be applied more broadly to other historically important sites and artefacts.

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Categories and Subject Descriptors

• Human-centered computing ~ Human computer interaction (HCI) • Human-centered computing ~ Virtual reality • Human-centered computing ~ Visualization

Keywords

3-Dimensional; 3D Scanning; Heritage Preservation; Forensics; Virtual Reality; Augmented Reality; Interactive Experience; Interactive Realities.

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1. INTRODUCTION

The Willandra trackways, are truly a hidden treasure of Australian human history. They allow us a very personal link to the past of human habitation of Australia that stretches back 20,000 years. The ancient trackways are located in the Willandra lakes region, in a world heritage listed site that is part of the Mungo National Park. The Willandra lakes, as we see them today, are a dry, sandy and arid region in the far west of New South Wales in Australia around 700km West of Sydney (see Figures 1 and 2) [1]. Each year more than 50,000 tourists visit this region for its historic significance, each trying to make a personal link back to the Australians of 20,000+ years past [2].

Figure 1. The Willandra Lakes Region [1]

Figure 2. Willandras' Dry Arid Countryside [1]

The regions historic value, and the reason so many tourists visit, comes from its many priceless historic sites and artifacts, all of which stem from what must have been a vibrant indigenous

community that lived there for more than 40,000 years (and whose decendents continue to do so today).
The region holds a number of areas and items of interest, the oldest of these having been carbon dated back (although dates are contentious) to as far as 50,000 years. It is important to note that there is ongoing debate and discussion, particularly in the archaeological community, regarding the specific dates for sites and artifacts, but it is broadly supported that at least 45,000 years of human habitation is strongly supported in this region [2,3,4].

Although there are many sites and items of interest in the Willandra lakes region, the most widely known and readily identified of these are:

Mungo Lady / Mungo Woman

The first human remains found in the region, were in the form of a burnt adult human female skeleton (jaw bone initial discovery), labeled “Mungo Lady” and discovered in a dry lakebed (Lake Mungo) in 1968 by geologist Jim Bowler [5]. He was in the area looking at geological evidence of landscape and climate change that occurred millions of years earlier, as the inland sea dried up and the lakes formed (today they have all dried up and it's a sandy arid area, but the landscapes of the past, still show their past presence (at large scale (satellite images (see Figure 3)) and small scale (in sediment layers uncovered (see Figure 4)))).

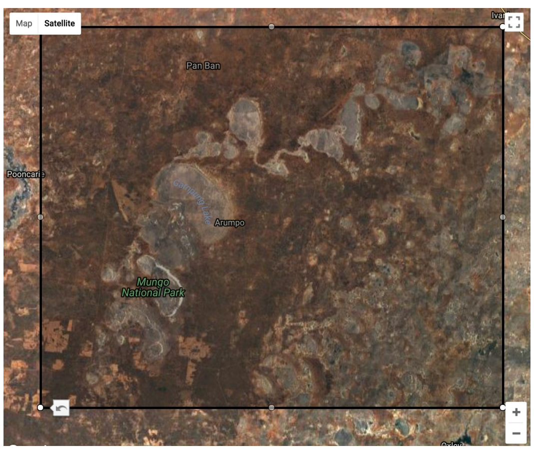

Figure 3. Aerial Satellite View of lake region

Figure 4. Sediment layers in eroded lakebeds [6]

It is in these old lakebeds and the eroded clay/sand walls (and their sediment layers) that he discovered the burnt bone fragments by accident, describing the experience as finding:

“"the very presence of humanity itself"
Quote from Jim Bowler 1967

Further work, involving archaeologists John Mulvaney and Rhys Jones in 1968 uncovered further bones and through this work a more complete picture of Mungo Lady was developed [4,5,6,7].

Figure 5. Archaeologists at Mungo site 1974 [1]

This work showed that not only was Mungo Lady the oldest evidence of human habitation in Australia (40,000-42,000 years by current estimates) but that her remains were clearly an example of a cremation. This site is one of the first examples of cremation to be found anywhere in the world and the fact that our earliest known Australians mourned for those who had passed away, and carried out specific cremation practices, is of international and cultural significance [5,7,8].

Mungo Man

The second set of human remains (a burnt adult male skeleton, skull was initial discovery (see Figure 6)) was located just 450m from the Mungo Lady site and was discovered in 1974, also by Jim Bowler, and also in the dry Lake Mungo play-pans.

Figure 6. Mungo Man excavations (Anthea Carstairs & Dr Wilfred Shawcross 1974 [6]

Carbon dating has now placed the age of this skeleton at 42,000 years and it is accepted as the oldest known example of human remains in Australia (and with other non-human evidence indicates that the region had active human habitation from around 50,000 years ago [4,9,10].

Willandra Trackways

Unlike the other two key finds, those being human bones, the Willandra trackways are a set of ice-age footprints, embedded into the clay-pan (around 20,000 years ago by our first Australians walking or running across the clay-pans and leaving their footprints preserved in the mud (see Figure 9 & 10)), in time these hardened, covered over with sand and sediment, to then, eventually be uncovered by shifting sands/erosion and found by researchers. The trackway was discovered in 2003 as part of an archaeological survey [9,10,11,12,13,14].

Figure 9. A trackway footprint (high resolution photo capture)

The erosion that impacts the area means that areas are being exposed and recovered on a regular basis and new finds are an ongoing outcome of this situation. The nature of this covering and un-covering has provided an ideal environment for trackways to be protected for long periods. In the case of the well-known Willandra trackways they were only found in 2003, but there may well be many others hidden beneath the sands of the Mungo National Park.
Detailed research and analysis has identified that the preserved footprints are around 20,000 years old and contain not a single persons track, but a combination of tracks including men, women, and children engaged in differing activities (walk, run). And due to the quality of their preservation it is possible to understand something of the story that each set of footprints holds.

Figure 10. The trackways [2]

The Willandra trackways are not only a valuable tool in understanding our Australian past, but they are also the oldest set of footprints ever found in Australia, and the largest set of ice-age footprints in the world.

Although these major finds have been most widely reported, the region has numerous other sites and items of interest, all of which add to the rich tapestry of ancient life stories that the region holds. In many ways it is not purely the data of the sites and artifacts that are critical, but also the stories that they tell, and the stories that have been passed down through the indigenous communities who live there. Only when we bring all of the pieces together can we create an engaging digital virtual experience.

2. THE STORIES OF WILLANDRA

As the introduction section demonstrates there are many valuable historical stories hidden within the Willandra lakes region. From the long term (geological time based) environmental changes that saw the region go from an inland sea, to a series of lakes, to drying lakebeds (when footprints were pushed into soft shallow mud) and eventually a dry arid space (as we see today). These long time frame stories sit alongside the more human stories of the ancient, ice-age Willandra communities, featuring people that lived along the drying lakesides (these would include Mungo Lady, Mungo Man and the people who made the track-way footprints). Much like today, people have a tendency to live near water and the ancient people of the Willandra region appear to be no different. Archaeological analysis of hearth remains and sediment layers from this ice-age period indicate that the Willandra waterways held fish and shellfish and that the earlier people (when lake water levels were high) would most likely have lived an enjoyable lakeside life. As the ice-age period approached the water levels in the lakes dropped leaving wet claypans. For visitors today, it can be hard to imagine a lakeside world (given its remote and arid setting) but such a world existed for our ice-age Australians.

2.1 Trackways Tell Us More

The wonderful thing about the trackways is that they are large enough (currently around the size of a standard tennis court, see Figure 10) to give us more than a single footprint. Instead they offer a form of historic story (or in this case stories) captured in the clay.
An excellent example of this is the set of tracks that, as described by archaeologists Harvey Johnston, Michael Westaway and Steve Webb [11,12,13,14,15], indicate a group crossing the clay-pan. The group consisted of several adults, adolescents and children (perhaps a family group). Archaeological analysis has been able to identify these individuals through the size of footprints, stride length and depth of mud penetration. Understanding the characters in the scene is only part of what the track-way can tell us. In this case we see the group of prints walk across the pan, but we also see a set of footprints break away to the side, then turn and come back. These prints are those of a younger member of the group (with a smaller footprint). It is easy to imagine a family group where a young child wanders away and is called back. Although a simple story it is this human touch and the obvious links to any young family today (with the common story of youngsters who wander off) that helps us gain a sense of understanding and association with Australias oldest known people.

In addition to the family tracks, the track-ways hold other series of footprints that are just as engaging. In one there is a set of larger/heavier prints (most likely men) that are moving more quickly (larger stride length and deeper mud penetration), in fact running. Once again it is easy to imagine a hunting party chasing prey or a number of other possible, very human stories.

The footprints are easily recognized, as humans, but there are also other marks in the claypans that may tell us stories. An example of these is a set of small crescent shapes, believed by some, including the local Pintubi people, to be marks made by children in the claypan [14]. Although this possibly true story is harder to confirm, it highlights an important part of generating engagement with the viewer. Being a contested story in no way makes it less relevant, in fact, the fact that it is contested makes it something of interest to an audience, as they want to see it and judge for themselves. Much like the track-ways, where the viewer can imagine how the people behaved, the possible finger artworks/marks have an element of the certain and an element of the unknown that needs to be imagined.

Archaeological and scientific analysis plays a crucial role in obtaining and clarifying the known details. The potential to use this information to then create a framework, in the form of a digital interactive system (game/AR/VR) into which the viewer could enter and experience the environment offers potential and is the core concept behind this research project.

2.2 The Hidden Story

The wonderful stories described are tightly linked to the actual track-ways, and the ability for people to imagine the possibilities relies on them being able to experience those very track-ways. Unfortunately the real physical track-ways (as seen in Figure 10) are fragile and at risk of damage (from both people and environmental factors (erosion, changes in underground water level cracking claypan)). In order to protect the site it was, in 2007, covered with sand (much as nature covered and protected it for thousands of years). Figure 11 shows the physical site today (including its full sand cover), and sharply highlights the need for other mechanisms for the broader community to experience and gain connection with the valuable track-ways and the stories of the region.

Figure 11. The hidden trackways [2]

As is the case for so much history and culture, the greatest source of information is the people themselves. In the case of Willandra we are fortunate to have the descendants of the very people who made the footprints, still living in the region today. The regions indigenous tribes actively seek to keep the history and culture alive, as the Visit Mungo National Park site states [2]:

"The Paakantji, Ngyiampaa and Mutthi Mutthi people walk here in the footsteps of their ancestors, ensuring their children grow strong in their culture. The tribal groups also seek to share their knowledge of Country with visitors to Mungo National Park."

Capturing these human stories, passed down through the generations is just as, if not more important than the digital and archaeological data capture, and it plays a key role in how this research project seeks to develop the digital experiences for the Willandra lakes. It is these human stories, through 3D computer animation and play based storytelling that will engage an audience. Earlier work in this research project has clearly demonstrated the power of interactive play based digital tools for engagement, learning and information presentation [REFS].

3. DATA CAPTURE & SCANNING

As discussed in the earlier sections the Willandra track-ways have been actively analyzed over an extended period. The bulk of this work has been archaeological study focused on academic knowledge. This research projects focus is on utilizing the pool of academic knowledge, linking it to cultural stories from the tribal groups, mixing all of that with leading edge digital data capture techniques (including 3D scanning, satellite imagery and height-map data, photogrammetry, environment capture) to finally produce virtual experiences that allow the user to engage with the world of the Willandra track-ways through digital means including Virtual Reality, Augmented Reality and gameplay.

The first stage of this process is the capture of the physical site data. This data needs to exist at several different levels of quality/detail. At the initial distant level (for example as you fly in over the whole region (which is hundreds of kilometers across)) the data needs to be low 3D quality (low polygon count per meter) but have high texture quality (surface images). This type of point of view is useful when thinking about the stories involving the very long time-frames (such as geological time) and allowing the user to see the inland sea slowly empty, the lakes form and slowly fade away into the arid landscape of today. Satellite imagery and satellite based height map scan data (obtained from NASAs datasets) was used for this "large scale" world view and allowed coverage of an area as shown in Figure 3. In an interactive world sense this gives the user a pilot like view of the environment (see Figure 12 for an example of the in game point of view).

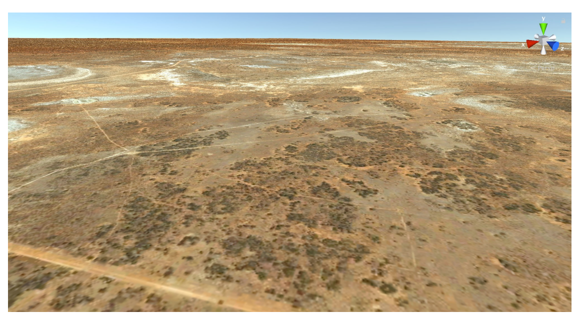

Figure 12. Large scale, lower detail view

At the more personal level, the user needs to interact with the trackways "on the "ground" and this requires a higher level of 3D detail. To obtain this 3D scanned data is used to build a world where each footprint has actual depth and detail. This involves a complex workflow to capture, using lazer scanning technologies, the scene. Following the initial capture the data must be post-processed (merging and associating sections together) into a point cloud dataset.

The point cloud format is useful, particularly for scientific analysis, and always looks very good in the scanner software tools, but unfortunately the point cloud format is also very inefficient in terms of computer graphics performance. For example a small scanned section of the track-ways (as shown in Figure 13) can have as many as 10-30 million points. This makes it highly accurate and useful for detailed scientific analysis, but unusable for interactive environments such as VR/AR and games.

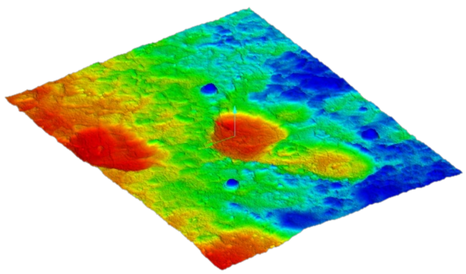

Figure 13. Example of a 3D lazer scanned footprint

Interactive systems, such as games are generally based in polygon based rendering systems and the world of games design has long been focused on the efficient use of polygon counts. Games (and this is even more relevant for AR/VR where the system must render two points of view (left and right eye) in real-time) regularly utilize tricks to create rich visuals without using high polygon counts (examples include use of complex texture maps on simple planar objects to give the appearance of 3D complexity without the po]ygon count).

Given this issue, the super high quality scan data of each footprint then needs to be simplified to be able to run smoothly in a VR/AR/game system. This is no simple task, just converting the data from point cloud to polygon can be problematic. Numerous techniques and algorithms exist including using nearest neighbor, triangulation and others (like rolling ball approaches) but all are slow and often inaccurate. This is too large a topic to cover here but the key point is that just converting the data to polygons is an arduous and time-consuming task. Once converted the data must then be simplified through polygon reduction techniques. A simple approach would be to just use poly reduction on the whole footprint, but this causes damage to key areas. The approach adopted for this dataset was to manually segment the footprint into high and low quality regions and then use more or less aggressive polygon reduction (for example in the clay-pan around the foot be very aggressive (reduce to very few polys) and use quality textures for detail. For the key areas (eg. toes) use higher quality 3D data and less aggressive polygon reduction.

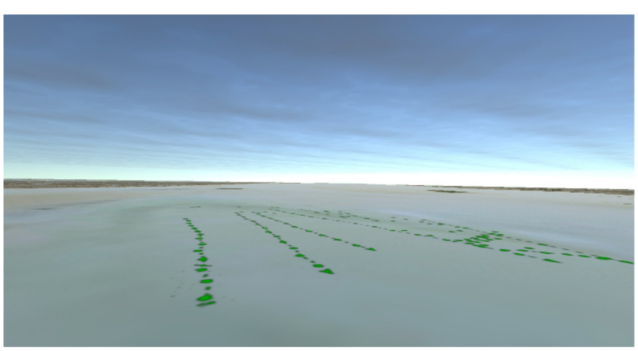

Figure 14. The virtual trackway

This was effective and provided a suitable dataset for game implementation (see Figure 14 for an example screen shot of the "virtual track-way").

Interactive play based systems, such as games/VR/AR offer the potential to allow the user to virtually visit the location and thus enable the track-ways to reach a larger audience.

The trial system we implemented has shown the potential of the approach, the technologies and workflows needed to take a cold historic site and make an interactive environment. There is clearly still much to do, and the project, which is currently only in the first phase will continue to expand and extend into this exciting field.

4. CONCLUSION

The Willandra region is home to some of Australia and the world's most valuable historic sites. It is clear that the stories held in this region offer powerful links to culture and history for many, yet they are currently completely hidden from view. This research project demonstrated techniques to allow the capture of the physical data and its conversion into workable real-time interactive systems. Brining this workflow together with knowledge from archaeological studies and regional tribal knowledge will enable those stories to be told to a new and much broader audience.

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Unreal Realities: Non-Photorealistic Rendering in Virtual Reality

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Abstract

Virtual Reality (VR) is a rapidly growing field, disrupting many industries, such as video games, engineering, architecture, and medical visualization. Designing VR experiences involves the use of digital technology and rendered 3D graphics to create immersive virtual environments. While traditional user interfaces require users to view and interact with a screen, VR systems place the user inside a virtual environment through the use of a head mounted display (HMD). This form of user interface has implications on how rendered graphics are perceived and interpreted. One rendering technique used extensively in the design and construction of virtual environments is Non-Photorealistic Rendering (NPR). NPR is primarily concerned with providing opportunity for a wide variety of expressive rendering styles such as toon, hatching and outline shaders.

This paper examines Non-Photorealistic Rendering techniques for virtual reality experiences, specifically focusing on strategies applied to achieve characteristics of toon, hatching and outline shaders, in virtual reality contexts. Through first identifying the common features traditionally used for NPR and then reconstructing these features in a virtual reality context the project illuminates unique considerations for practitioners implementing NPR effects in VR.

Keywords

Virtual Reality, Non-Photorealistic Rendering, Virtual Environments

Introduction

The notion of virtual reality has existed for some time. It was the technical advancements of the late 1980's that made the concept a reality [11]. VR is distinct from traditional forms of screen based media such as film, in that the user is immersed within a virtual environment [3]. This effect is achieved through technology such as "three-dimensional, stereoscopic, head-tracked displays, hand/body tracking, and binaural sound [3]. Over the last decade this technology has continued to advance, allowing virtual reality systems to become mass produced increasing availability to consumers and independent developers. As a result, these systems are rapidly being adopted by developers of digital content for purposes such as education and entertainment. When creating virtual world experiences designers transitioning from traditional screen media projects are now faced with the challenge of rendering digital content within a head mounted display. One field of rendering that is relevant to virtual reality projects is non-photorealistic rendering, as it allows designers to express many different artistic styles [10]. Non-photorealistic rendering encapsulates many forms and is derived from styles within the arts such as animated cartoons, painting, drawing and technical illustration [9]. This project examines non-photorealistic rendering as an important component of virtual reality creation, in order to identify implications for the designers of these experiences.

Existing Knowledge

Non-Photorealistic Rendering

Non-photorealistic rendering is a field of computer graphics described as having "two complimentary goals: the communication of information using images; and rendering images in interesting and novel visual styles which are free of the traditional computer graphics constraint of producing images which are 'life-like'" [9]. Non-photorealistic rendering can allow images to communicate information more effectively because the images are "free of the complications of shadows and reflections" [9]. This problem is described by Gooch, Gooch, Shirley, & Cohen [4] who state that realistic "phong-shaded 3D imagery does not provide geometric information of the same richness as human-drawn technical illustrations". Human drawn technical illustrations are frequently used for non-photorealistic rendering due to its need to communicate information effectively [4]. Another aspect of non-photorealistic rendering is the ability to create computer graphics effects that mimic "aesthetic human artistic styles"[9]. In their paper 'State of the Art Non-Photorealistic Rendering (NPR) Techniques' Sayeed & Howard[9] categorize non-photorealistic rendering techniques into five broad sections: stylized lighting, silhouettes and edges, volume rendering, pen-and-ink hatching, and engraving. These categories are then further defined by whether they are calculated in object space or screen space and if they have frame coherence. Three prevalent categories used in virtual reality projects are: stylized lighting, silhouettes and edges, and pen-and-ink hatching.

Non-Photorealistic Rendering in Virtual Reality

Existing knowledge surrounding the use of non-photorealistic rendering for virtual reality has already identified several important considerations. These are largely related to the methods in which virtual reality systems influence our visual perception. The nature of this is described by Richardt, Kyprianidis, & Dodgson[8] stating that "In the real world, the two views created by our eyes are inherently consistent, as they are both projections of the same 3D world. However, this is not necessarily the case for NPR techniques". As a result, the project involved the core features of NPR effects that indicate compatibility with virtual reality environments. These are temporal coherence, object space coherence and stereoscopic coherence[10].

Temporal Coherence

The notion of temporal coherence is an important consideration when creating non-photorealistic effects in virtual environments[7][8][9][10]. There are a number of different terms used to describe temporal coherence in contemporary literature such as frame coherence[7] and fluent image rendering[10]. This study applies the definition by Sayeed & Howard[9] who describe temporal coherence as a sequence's ability to maintain appearance over multiple frames without appearing to 'jump' or distort. They consider temporal coherence to be influential, given that most implementations of VE's are not static. Therefore, it is important that effects show consistency over time.

Object and Image Space Coherence

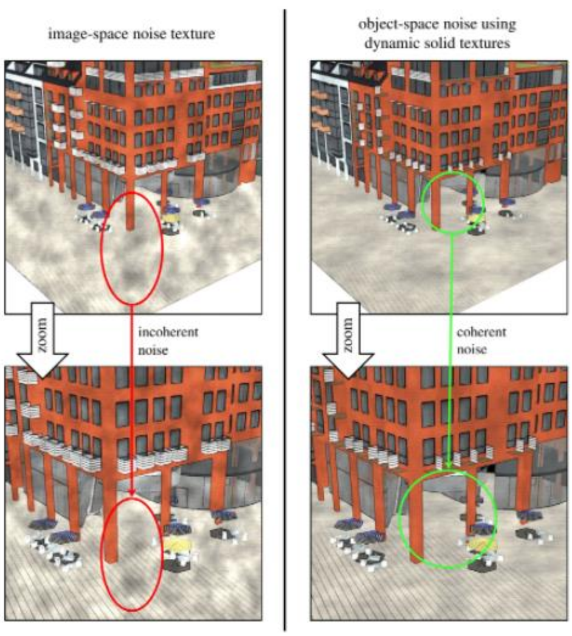

Figure 1. Comparing image-space and object-space to demonstrate the shower door effect[8].

When examining temporal coherence effects within virtual environments consideration must be given to the concepts of object and image space coherence. Object space coherence in virtual environment rendering involves a process in which the system calculates and renders levels of visual abstraction based on the position and relationship of objects being rendered in the scene. Image space coherence however calculates levels of visual abstraction based on the position of the viewers coordinates within the scene. When investigating these two forms of effects rendering, Richardt, Kyprianidis & Dodgson[8] found that the image space rendering methods were more likely to experience unwanted side effects such as the shower door effect. The shower door effect describes a virtual environment that appears as if viewed through a shower door or similar filter as shown in figure 1[8]. The shower door effect has previously been identified as having negative implications on temporal coherence[7]. Richardt, Kyprianidis, & Dodgson[8] also found that effects rendered using object space methods were more likely to be temporally coherent than those derived from image space effects. The current study therefore considers the object space method of image rendering as being more likely to offer positive experiences for viewers in regard to temporal coherence and reducing incidences of issues like the shower door effect.

Stereoscopic Coherence

Stereoscopic Coherence is identified by Schultz[10] as describing effects which are compatible with stereoscopic rendering and is a key feature of NPR effects in VR. All the features of NPR effects discussed are critical to creating stereoscopically coherent NPR effects in VR. Richardt, Kyprianidis, & Dodgson [8] identify temporally coherent effects as more likely to be stereoscopically coherent. Their work aimed to test the compatibility of object space versus image space non-photorealistic effects in stereoscopy. Their study found that object space effects were much preferred.

> "Overall, participants also found the object-based method more comfortable to watch. … It appears that stereo coherence is closely related to temporal coherence, as object-based techniques are also more likely to be temporally coherent than image-based techniques. However, further research is warranted to study this relationship in more detail" [8].

The effects created by this work should use these features as a template when considering how to create NPR effects which are suitable for VR.

Non-Photorealistic Rendering in Virtual Reality

This research project was conducted through a participatory action research approach in line with Kemmis & McTaggart[6]. In this approach the researcher is embedded in the study and critiques the research process and journey through collaborative discussions, reflection and reflexivity. Therefore the investigation involved the implementation of non-photorealistic effects in virtual reality systems through the creation and rendering of a virtual environment. Data collection and analysis was gathered through contemporary literature combined with a series of rendering prototypes. These prototypes focus on the implementation of non-photorealistic rendering in the context of virtual reality and utilize the Unity game engine.

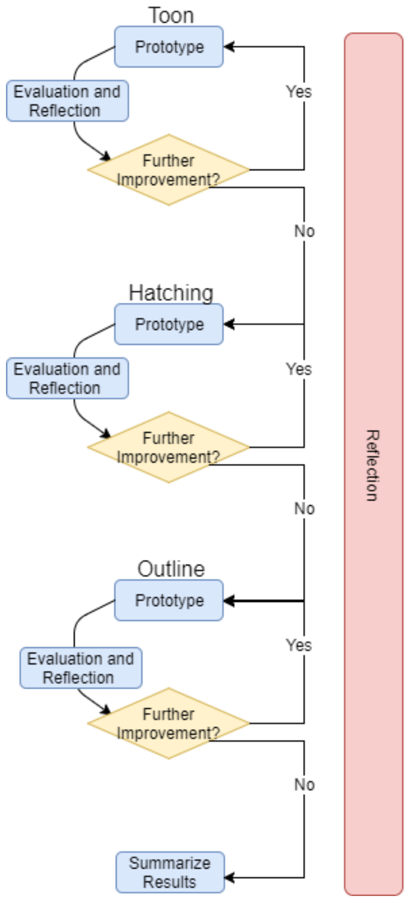

Figure 2. Overview of Research Methods

During each phase of evaluation, as shown in figure 2, a new implementation of the effect was created with any changes to improve compatibility of the effect with VR implemented. Compatibility is measured though the effect presenting with the key features of NPR described above; Object Space, Temporal, and Stereoscopic Coherence. This process was applied to three specific non-photorealistic effects commonly found within virtual environment design; toon shading, hatching and outlines. Although other forms of non-photorealistic effects are also found within virtual environments they lie outside the scope of this project. These effects were selected as they represent a diverse set of features of non-photorealistic rendering. Data for this study was derived from observation, reflection and discussion and is compiled in a development journal. Regular build snapshots were created throughout development in addition to a source controlled repository of the project.

Prototyping, Result, and Evaluation

Toon Shaders

Toon shading was selected as an example of stylized lighting for this study. Stylized lighting effects use a calculation to replace realistic shading models with false colours. A cartoon shading model normalises lighting values to give a sharp cut off between differently lit areas of a model reminiscent of cartoon scene as shown in figure 3[10]. Cartoon lighting is a distinctive style characterised by large uniformly or widely banded coloured surfaces with detail largely restricted to outlines" [9]. While there are many different methods described to create this effect, all can be broken down into two sections; the lighting model, and the abstraction. Most effects base their lighting model calculations on either Lambertian[5][1]. or Phong[4][2]. shading. Regardless of the lighting model used, the output of this stage is a luminosity value for each fragment. In traditional 3D rendering techniques this would be the value output for each fragment.

Figure 3. Example of toon shading[10].

The second part of an NPR toon effect, is the abstraction of the luminosity value to create the distinctive cell shaded effect. Again, two methods are popular; texture-lookup and procedural. The texture-lookup technique uses the luminosity value as a lookup value from a 1-dimensional texture which defines the shading of the fragment as shown in figure 4. This technique allows one shader to produce many different effects if using different 'toon ramp' textures and gives a lot of control to artists.

Figure 4. A black and white one-dimensional texture, with pixel positions from 0 to 1[5]

The procedural method contrasts the texture-lookup method by assigning colour values to ranges from the luminosity value in code. Figure 5 shows an example of this where luminosity values greater than 0.5 are shown as white, values less than 0.5 and greater than 0 are a dark gray and values less than 0 are black. Luminosity is represented in this example as 'nl', describes the dot product of the normal and the light vectors, representing how luminosity is calculated in the Lambertian lighting model[5].

```
if (nl > 0.5)
      color = vec4(1.0,1.0,1.0,1.0);
else if (nl > 0.0)
      color = vec4(0.33,0.33,0.33,1.0);
else
      color = vec4(0.0,0.0,0.0,1.0);
```

Figure 5. Code example for procedural toon ramp [5]

There is a consensus that specularity is an important part of toon shading effects as they convey "… information about

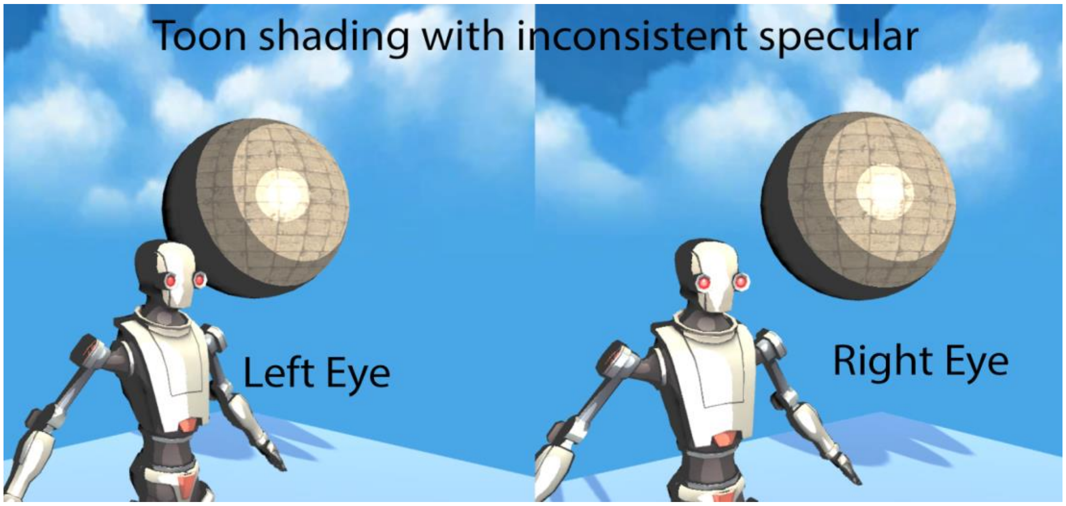

Figure 6. Example of stereoscopically inconsistent specular highlights in a toon shader.

surface type" [5]. The level of abstraction in this effect, especially when not using texture can lead to a lack of understanding in the view about the objects being rendered. Specular highlight help resolve this issue by "…provid[ing] visual feedback about the material type of an object (flat, shiny, metallic…)" [2].

Due to the use of traditional lighting models at the core of this effect, it was predicated that there would be minimal issues in a VR implementation. The exception to this is specularity. Specular highlights are a view-dependent effect that represents the properties of the material through the angle between the viewing direction and the light reflection vector [1].

The initial VR implementation of toon shading in this work used a Phong lighting model and procedural abstraction of luminosity for ease of implementation [5].

This version worked well in VR, despite a slight loss of depth information due to the flat shading with the exception of specularity. Specularity is a measure of how reflective a material is and is an important element in communicating information about surface textures in toon shaders [9]. Rendering specular highlights caused a cross eyed effect on non-uniform surfaces as predicted since each eye calculated a unique specular highlight. This can be seen in the specular highlight on the robot's head in figure 6. The distinctly different shapes of the highlight would lead to the area to the left of the robot's right eye being reflected in the right view and flat shaded in the left view. This causes a cross eyed effect when viewing this area. On uniform surfaces, such as a sphere, the highlight was stereoscopically coherent, since despite the view vector being different, there was consistency in the surface of the object. This meant the specular highlights stereoscopically resolved as a solid circle inside the sphere. This did not look like a specular highlight.

The main issue to resolve in the next iteration of the effect was the stereoscopically inconsistent specular highlights. To resolve the cross-eyed issue, and keep with the toon nature

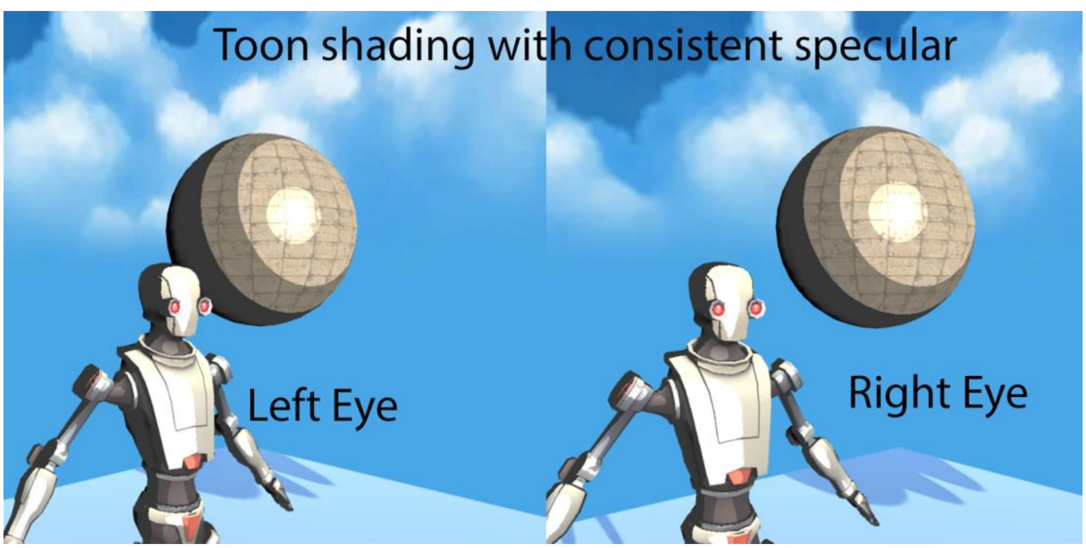

Figure 7. Example of stereoscopically consistent specular highlights in a toon shader.

of the effect, the specular highlight should not be stereoscopic and rather appear to be painted on the surface of the object. The loss of depth information is consistent with the cartoon goal of the effect.

To achieve this, the camera position used to calculate the specularity for each eye was replaced with the same global point representing a midpoint between the two eyes. This resulted in a less accurate specularity abstraction that was close enough to an accurate specular highlight to be believable but was also stereoscopically coherent because the same calculation was used for each eye. Figure 7 shows a consistently shaped specular highlight on the robot's head. The specular highlight on the sphere in figure 7 is also now consistent which can be identified by examining the constant distance from the left edge of the specular highlight and the darker band of diffuse lighting. This is opposed to the different distances in the inconsistent example in figure 6. This resolved the major issue identified with toon NPR effects in VR.

Hatching Shaders

Unlike, other NPR effects, Pen and Ink Hatching is a purely artistic effect, that does not aid in the communication of information. This is due to the limitations of the style, since it consisted only of monochrome pen stokes. The style can struggle to communicate the properties of a material. "This is solved through hatching, which is a technique that indicates curvature through stroke direction and surface texture, and lighting by stroke weight, density and rotated layering (also known as cross-hatching)"[9].

This work implemented a version of this effect described by Praun, Hoppe, Webb & Finkelstein[7]. Their method for Real-Time Hatching is calculated in object space so that it will be temporally coherent. Both of these features were previously identified as relevant features for VR. An important feature of Hatching Shaders identified by Praun, Hoppe, Webb & Finkelstein is consistent stroke width and density, even as an object moves further away from the viewer[7]. This has traditionally been a feature of image space hatching techniques, however, Praun, Hoppe, Webb & Finkelstein presented a method for achieving this consistency in object space using a Tonal Art Map (TAM). The TAM is a sequence of hatching textures, representing different levels of luminosity, with custom mipmaps that reduce the resolution of the texture, but not the scale of the strokes at each mipmap level as shown in figure 8. Mipmapping is a common technique in 3D graphics rendering to allow objects to sample a lower resolution version of a texture, if the object is further away from the camera. Using a TAM, as the object moves away from the viewer and different levels of the mipmap are sampled, the stroke width and density remains constant[7].

For our VR implementation, we were aware that the hatching shader constitutes a much stronger abstraction of the lighting model than toon shading. Thus, if specularity is included in the effect it should be calculated in a stereoscopically consistent fashion using the centre eye technique. However, as Praun, Hoppe, Webb & Finkelstein point out the strokes "character and aggregate arrangement suggests surface texture" [7]. Since the role of conveying information about the material can be left the TAM, specularity in the lighting calculation was left out of our implementation.

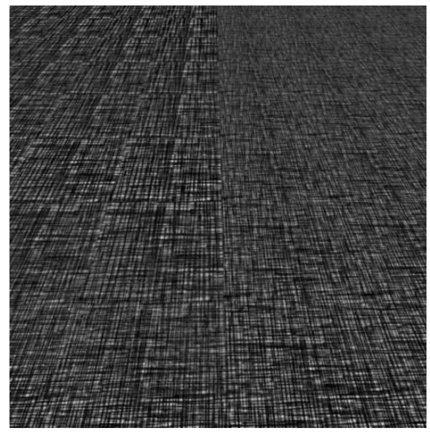

Figure 9. Comparing pen and ink hatching with and without TAMs. Left: with TAMs implemented for constant stroke width. Right: using traditional mipmaps without TAMs.

Since we predicted no complications with stereoscopic coherency, because the technique is object space coherent, our first iteration of this effect was setup to test the relative effectiveness of TAM's and traditional mipmaps. Figure 9 is a side by side of the two techniques on two planes receding into the distance. The left side shows TAMs implemented, as the strokes at the top of the image have the same width despite receding into the distance. The right side of the image shows traditional mipmapping where the texture reduces in resolution but not scale as the object recede.Both methods

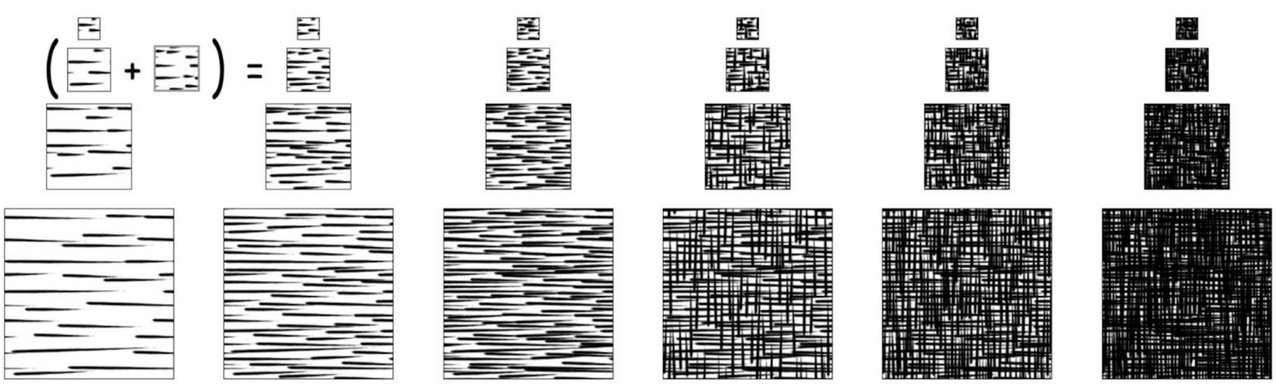

Figure 8. Example of stereoscopically inconsistent specular highlights in a toon shader[7].

presented no fundamental issues in terms of the core features of NPR compatibility with VR since both are Object Space, Temporally and Stereoscopically coherent. However, the need for consistent stroke width and density is part of making the effect appear as a 2D drawing, and while using the effect in VR this is still the goal in principle, we found that the stroke width remaining constant removed a vital depth cue, used to determine the size and scale of one's environment. We therefore found that the experience was better when the TAMs were not implemented, leaving the user with more depth cues.

Outline Shaders

Silhouettes and edges are a collection of techniques that mimic traditional line drawing methods because "line drawings constitute one of the most common and effective illustration styles" [9]. Rendering techniques in this category are used in "formal contexts such as technical illustration, architectural design and scientific diagrams" [9]. The delineation of internal edges, in addition to silhouettes, greatly increases the internal readability of the object [4]. This category of non-photorealistic rendering is also valuable in artistic contexts for its ability to evoke cartoons and sketches [9].

Our first implementation of outline shaders used a standard technique of rendering the object to be outlined in an initial shader pass, that is flat shaded in the desired outline colour, where the object vertices are scaled along their normals by the outline amount. The object can then be rendered on top of this silhouette normally if desired. The method works well in VR, as it is entirely object space coherent and temporally coherent. The limitations of this method in VR are the same as in traditional executions; models with hard edges the outline shape becomes discontinuous at the corners. This is demonstrated in the outline of the robots shoulder in figure 10. A range of other techniques for rendering outlines exist, however few seem to present issues specific to stereoscopic coherency based on their underling feature set as they are object space and temporally coherent.

Figure 10. Example of extruded normals outline shader without fill texture.

Results

NPR effects that do not feature spatial abstractions, like tone shading, should be naturally compatible with VR. However, NPR effects with spatial abstractions should use objects space calculations to prevent each eye from getting a different response where possible. Just as Image Space rendering in Real Time environments can be described as having a 'screen door' effect, effects in VR that are not stereoscopically coherent can have a 'cross eyed' effect where each eye is finding images that do not resolve stereoscopically. If an effect needs to use the view position or direction, thus being calculated in image space, it may benefit from calculating the abstraction for both eyes from a global centre point so that the abstraction is consistent across both eyes, forcing an images space effect to appear stereoscopically coherent, at the cost of accuracy.

Future Research

This work expounds the effect virtual reality has on a number of core features of NPR effects when implemented in a VR context. However, the importance of maintaining these features in the new medium was not investigated. This work discusses techniques for ensuring that the maximum amount of depth cues are maintained when implementing NPR effects in VR but does not assess the importance of these depth cues, or recommend a specific amount to maintain immersion. As this work focuses on the implementation of NPR effects in VR, issues such as user experience and immersion are outside of our scope. As an early Further work investigating the effect that different features of NPR effects have on users in VR could build off the results of this study.

Conclusion

The project illuminates unique considerations for practitioners implementing NPR effects in VR. Most effects which are compatible with real time environments will already have all the features needed to be suitable for VR. The main consideration specific to VR is large spatial abstractions, such as those found in the colour banding of toon shaders, or the addition of outlines. These abstractions only cause an issue if they are calculated using the view position or direction, since this means each eye will get a completely different image resulting in a cross eyed effect. However as the results of this study suggest, it may be possible to replace the view position with a global centre eye position that is consistent across each eye to make the effect stereoscopically coherent.

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Design and Production of a Customisable 3D Character Pipeline

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Abstract

One of the major barriers in creating a customisable 3D character is the lack of knowledge into the creative and technical pipeline required. Most games that have these kinds of systems are high budget games, with the artists and programmers having lifetimes worth of experience. These systems are also highly valued, and as such are often proprietary in nature, which means very little information on the actual construction is readily available. This research project aims to design a pipeline for creating a base character mesh tor single mesh to be used in a character creation system.

Keywords
3D, modelling, character, customisation, pipeline, animation

1. Introduction
Avatars and 3D characters are one of the most important aspects of game development, they are the conduit through which the player interacts with and experiences the game. As technology has advanced games have offered us higher levels of detail and character, and also in some games tools that offer a high level of customisation over the player's avatar. Customisation systems allow the player to alter a range of variables about the character, such as facial features, skin tone, physical attributes and even clothing and affectations. Whilst these are commonplace in mainstream games with high production values, knowledge of these systems is not commonly known.

3D game assets are comprised of polygons which create geometry or a mesh, how the polygons are placed and connected together is referred to as the model's topology. It is important that these meshes use polygon placement efficiently so as to be optimised for a real time game environment. Organic assets such as characters that will be animated require good edge flow and loop placement, so that they can be animated properly. Edges and loops refer to areas of the mesh that flow into each other, so the mesh can deform as expected.

Good topology is very important when the model is rigged, wherein a series of bones are created that move the mesh and allow for animation. When a mesh is moved in such a fashion it is referred to as being deformed, the bones that move the mesh are referred to as deform bones. A portion of this project will go over some of these aspects in more detail, with research pertaining to current standard practices in the games industry.

From there we will conduct a case study to analyse games that have customisation systems, and determine what the most important features are and hypothesise how they function. Much of these systems are reliant on the aforementioned topology and rigging phases of a character models creation. Much of the customisability comes from the scaling and offsetting of bones to deform the mesh, in this case the deformations are not for animations but purely to customise the mesh. Through these deformations an end user can define characters that are wholly unique. One of the major issues with such systems is that they are highly valued, and often proprietary in nature, as such there is very little information regarding the specifics on their creation.

This project aims to fill this gap in information through the development of a pipeline for the creation of a model and rig that can be used in a character creation system. This project will ultimately produce a pipeline for the creation of such a system, a pipeline being a series of steps and technical information. In the context of this project this pipeline will relate to the steps in creating a humanoid model with a rig, and specific technical steps in preparing it to be customisable within a game engine. It is important that the resulting model meets current industry standards in both terms of aesthetic, and optimisation to ensure many of our models can be in a real-time scene at once. Furthermore, this pipeline will create a single asset that can be modified within a game at run time that can be modified into many different characters.

Related Work
Feng et al. (2015) produced a paper that outlines the creation of an automated pipeline that takes a 3D scanned image of a humanoid, and creates an animatable model. To do so the system they created took the raw data of the 3D scan, and matched it to a morphable 3D model, or template they had created. These templates are blank generic models that focus on well-defined topology, that allow for high levels of customisation. This one template allows the creation of a variety of different body types, Feng et al. (2015) state that morphable models allow modification of physical attributes, such as height or weight. Once a match between original 3D scan, and most applicable template was found the system would adjust the mesh of the template to accurately portray the original 3D scan. The template used also allowed them to create an automatic rigging of the final model, which gave

accurate results due to the control provided by the creation of the template. The system was evaluated by comparing it to previously created systems and it was found to provide much more accurate representations due to the use of morphable templates.

Apostolakis and Daras (2013) produced a paper that outlined the creation of a system called 'The Reverie Avatar Authoring Tool' (RAAT). The RAAT provides a code base that developers can use as a framework for their character creation systems, which handles the database and application of assets created for the environment in question. Assets in this respect refer to different body parts, styles of hair, or aesthetics such as clothing or jewellery. The system allows the end developer to give the end user as much control over the customisation as they see fit. The system has a range of features outside this, predominantly in regard to integration with current web technology but also image capturing and integration. The RAAT is able to take images of faces and map them to generate a 3D model of a head, which is manipulated to match the image with a high level of accuracy. The image provided is then turned into a texture which is applied to the geometry of the 3D model, giving end users the ability to literally recreate themselves using actual photographs.

The RAAT can be tailored to suit many different types of environment and tackles similar technical issues in its pipeline that will be present in our final projects pipeline. Despite similarities in an overall goal to provide a solution to providing a customisable character solution, our project will focus more on the creation of the assets such a system would require. Furthermore, our projects final outcome will integrate the ideas of these last two papers, by providing a template character mesh that can be customised as desired. Our project will also concentrate on the practical pipeline of said asset creation into such a system, which neither of these papers cover.

Customization in video games is very important ant it is a part of the user experience (Kleinsmith and Gillies, 2013). This kind of customization allows players to distinguish the player's identity through the avatar, and it is a means to communicate a player's identity to other players. Their findings show that these are important aspects of player interaction, and that users have a desire to create unique characters

The ability to create a customised character is also an important factor when considering how players identify with their avatars and characters in games. Gaming culture has centred on the heterosexual white male as being the main demographic, yet as gaming has become more popularised and mainstream it has become clear that everyone plays video games. This is important for two reasons, firstly that game developers have an ethical responsibility to better represent a wider spectrum of their actual audience; but also a financial incentive to market toward demographics within the market that are simply not being catered to (van Reijmersdal, Jansz, Peters, van Noort, 2013).

These previous papers define and argue the importance, and identity roles of avatars in video games. Through these papers I have established that they are both a highly desired feature in video games; that they increase the players' ability to represent themselves better in a game environment; and that it empowers the user to create avatars they truly find engaging. Furthermore I have posited that character creation systems have a high importance to the gaming industry in terms of accessing a wider audience, which would widen their demographics and conversely raise their potential profits. All of these factors also tie into player immersion, another important element that distinguishes video games from other mediums. The paper 'Stimulating Psychological Attachments in Narrative Games: Engaging Players with Game Characters' state that a players level of engagement is described and quantified using the term immersion (Mallon, Lynch, 2014), and that the game developers true desire is to have the player fully immersed in the game world, to create a seamless experience from start to finish. "the psychological and emotional connections players make to a game are critical to their enjoyment … The psychological absorption and emotional connection that players can experience when playing games is a factor that game creators aspire to invoke." Mallon, Lynch 2014). The paper focusses on what elements truly engage and connect a player to the character they are playing, encompassing the entire spectrum of media that goes into games. However the points raised in the paper when correlated to other findings work toward the same goal, of including and allowing the player to become a true part of the gameplay experience. Without the ability to represent themselves, in a lot of cases they will never feel truly immersed. There is no amount of marketing research or focus group testing that can design a character that will please every demographic, giving the player the ability to design their own is not only providing a desired feature, it just makes sense.

These systems are for the most part, usually beholden to big companies that have the ability to invest in the technology. These systems are fairly common in such high budget games, and commonly accepted and expected of audiences, and especially so in online multiplayer style games; yet information on how to create these systems, is severely lacking in the academic space due to the proprietary nature of the companies who hold said technologies.

The literature review identifies the gap that is creation of a character customisation system which allows the player to create a fully unique character of their own. This system will be created from the ground up, and encompass the entire 3D workflow and pipeline, along with implementation into a game engine via C# scripts. This workflow and pipeline will also revolve around a dependency on being accessible and affordable to indie developers and students alike. The proposed workflow and pipeline will be for the most part application agnostic, furthermore, whilst the application of this workflow will be specific to creating biped humanoid characters, this workflow and pipeline could be applied to any character or creature the developer wishes to create.

Character Creation Pipeline

A case study was conducted on two critically acclaimed games, Fallout 4 by Bethesda Softworks, and Champions Online by Cryptic Studios. They are both hugely popular games that were also commercially successful, both have character creation systems that boast high levels of modifiable aspects. The following pipeline outlines methods for recreating aspects of the systems found in these games.

Modelling Process

The construction of our character asset will start with the modelling of the base mesh, concentrating on the creation of a basic humanoid. This process will attempt to recreate the level of quality presented by the case studies, which requires altering conventional modelling techniques to create a pipeline that will make these features possible to implement. In this first step we are creating a base mesh that will be aiming for a stylised realism approach, though could be applied to any style.

Defining the humanoid body

Our base mesh will be as nondescript as possible, with an ectomorph body type. An ectomorph body type is lean, and an average between the two other standard body types, endomorph (pear shaped) and mesomorph (muscular). The reason for our choice to model the mesh in this fashion is that it will in later steps be much easier to move between other body types from what is essentially an average.

For this phase of the modelling process, we are focussing primarily on the major proportions of a humanoid, with no detail being created in the face. Figure 1 shows the first pass of the base mesh creation, focussing on getting proportions and geometry nicely laid out.

In modelling characters it is important to account for animations, bad geometry and topology will result in artifacts or not being animatable at all. For this reason it is important to use loops, which are polygons that follow each other across the surface of a model. Creating good topology will mean the geometry will deform correctly, and prevent polygons from breaking and clipping through their neighbours.

In Figure 1 we can see that some areas of the mesh are denser than others, whilst it is important to keep your mesh as evenly spaced as possible (mostly to make animation easier, but also concerning texture layouts), more detailed areas of the mesh require denser amounts of geometry. This is especially true in areas such as the hands, feet, and face. The extra geometry isn't simply to add definition to the model, but also to allow for better deformation of the mesh during animation. In some cases during our process however, we will be adding geometry purely to allow for customisation of the character.

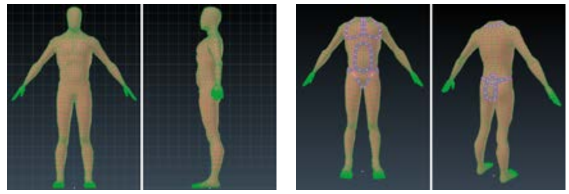

Figure 1: Left: Front and side view of the base mesh. Right: Deformation controlled with loops.

Overall in most cases the topology and edge-flow of the model should remain consistent with conventional modelling techniques, with denser areas of geometry to account for ability to scale and morph certain features.

One element of the topology that will differ from normal models will be the necessity to have loops around any musculature that will be morphed. This will be necessary so that unwanted stretching doesn't occur. This will mean a denser overall mesh than what is always needed, but is necessary in order to make the character work.

Modelling of the Head and Face

The construction of the head, and more specifically the face further shows the need to create dense topology around heavily deformed areas. In Figure *2* we can see the major loops around the mouth, eyes, chin and nose areas. These loops will ensure that facial animations will deform the mesh as expected. Another important aspect of this mesh is that the features are very non-descript, which as previously mentioned will better allow for customisation. These loops are standard in most humanoid facial topology, however for the purposes of our project we will be altering this mesh somewhat to allow for better customisation.

One case is the nose area, for the use case of the character customisation we are creating, we want drastic cartoony amounts of alteration to be possible. The current level of topology in the nose area is simply not able to account for this. In Figure 2 we see that the topology becomes highly stretched and distorted when deformed to a desired extent. To solve this issue, we must add geometry in the specific areas we wish to deform, but this must remain both efficient and follow the basic tenets of good topology. For this specific case, we have added more geometry to achieve the desired result, whilst still maintaining the core loops in these areas. Throughout the process of rigging the character further geometry will be added in this fashion where needed.

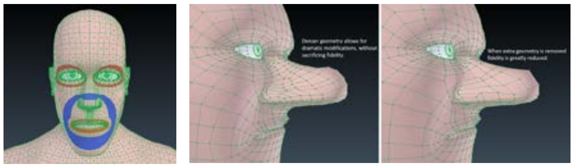

Figure 2: Left: Facial topology/major face loops. Right: Nose topology for modification.

The result is the same level of deformation, with a large cartoony style nose, but with less stretching and distortion. This solution is used all throughout the base mesh, in areas that will require similar forms of deformation.

UV Unwrapping, Texturing and Material Groups

Unwrapping a model is the process wherein the mesh is divided into sections, which is laid out like a skin in 2D space. This allows textures to be created through the creation of a diffuse (base colour and texture), and different types of maps such as normal, roughness or emission. Unwrapping of our model will require us to identify the functionality we want from the final asset. For the purposes of this project, the end user should be able to layer aesthetics such as tattoos or scars across the body. This will require that the model be unwrapped in a certain fashion to allow for this functionality.

Unwrapping

To unwrap our model we lay seams along polygon edges to designate where the mesh should be split when laid out on the UV grid. There is no one correct way to unwrap an object, each case will be unique depending on the geometry of the overall mesh. There are however several factors to take into account when unwrapping, which will lead to a better more usable UV set. The most major factor is evenly spacing your UV's, this means that the unwrap is as evenly spaced as possible to reduce stretching in the texture. In the figure below we can see examples of an well spaced in comparison to a stretched unwrap of the same mesh.

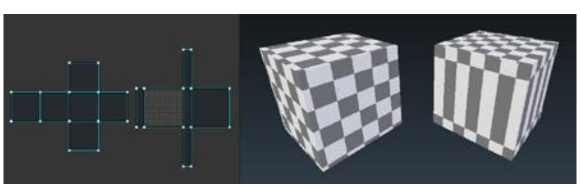

Figure 3: Geometry that is unwrapped incorrectly or not spaced evenly will result in stretching.

Layered Textures

Another point to consider are areas of the characters textures that can be customised. In Fallout 4 the player is able to modify the textures of the face, adding scars, makeup, or freckles and moles. For our example we will be adding elements such as tattoos, face paint, or scars that we will refer to as decals. To achieve this we will use multiple texture sets that are layered over each other.

There are two methods explored in this project to achieve the desired result, both with positive and negatives. The first is separating the base mesh up into smaller islands or areas, such as face, left arm, right arm, legs etc.. This way each individual piece can have its own UV and texture assigned to it. When the end user chooses a decal to apply, the texture with the chosen decal is activated and replaces the current texture.

The benefit to this method is it is simpler to design and implement, and has a lower number of variables that have to be stored at run time. It means however that the decals are static, their scale, location, and colour cannot be changed as they are part of the overall texture including the underlying skin.

The second method is true layering of textures, where a second alpha mapped texture on transparency is laid over the base texture. In this method the original UVs are used, and the base mesh is unwrapped as it normally would be. Just like the previous method the user can choose a decal, at which point the chosen texture is activated and layered over the base texture.

The major benefits to this method is the fact the overlaid texture can be moved, scaled, and recoloured. This means a lot more customisability, but also means that a lot more variables need to be taken into account. In terms of memory overhead these variables, which would track data such as x/y location on the UV, offset values, and RGB value would be negligible; however the code base to handle the management of this system would require a lot more work than the previous solution.

In terms of efficiency, the second method would be more expensive due to it requiring multiple textures, and multiple materials which would result in many more draw calls to render. This could be offset through the use of a shader, which could combine several materials and their unique textures into one texture for use at runtime. This would result in less draw calls, and take up less memory. This kind of optimisation is however outside the scope of this project.

Colour Variation

When creating UV's for the character certain aspects of the customisation system will have to be taken into account. The most basic form of this will be separating out any parts of the model that can have their colour changed, such as skin pigment or hair colour. To achieve this the UV's will be placed upon unique texture sheets, so as the hue can be controlled simply through modifying the diffuse RGB value of the material. This will mean that these textures are created using only greyscale, so that the textures are basically only showing shadow/depth/texture, with the colour being controlled completely through the materials diffuse RGB.

UV Layout

Our UV co-ordinates will be laid out in a conventional way, focussing on efficiency and using as much of the texture space as possible, whilst minimising the stretching of textures. For the purposes and scope of this project we will be using these UV's and simply layering textures with unique materials on top. In the figure below is an example of a standard humanoid model that has been unwrapped in a conventional fashion.

Materials

As discussed in the previous section, material use will be limited through the use of a shader to deal with any customisation options made available to the end user. As such, like in conventional modelling preparation separate materials will only be used for actual different materials and textures. For example, clothing will be predominantly matte in finish, skin very similar with slightly more specular, and any metal or plastic elements will be shiny and reflective.

Materials are set to a model through material ID's, wherein the mesh is separated into different groupings and assigned one of the ID's. In the modelling program being used, there is no use in setting up the materials (in terms of texture, specular, glossiness etc...) though this can be done sometimes to provide a preview of the end result.
More often the model is brought into a separate application, or even the engine desired for the final application, in this case Unity. Here the materials are set up and given values so they accurately match the desired end result.

This materials will be set up in a way that allows them to be instanced, meaning that certain variables associated with them, specifically hue can be altered and saved at runtime. This will allow for multiple characters created from the system to be on screen at once using unique variants of the base materials.

Rigging the Character

A character's rig is a series of bones that the mesh is weighted to, the bones can then be used to move the mesh and thus create animations. This is often referred to as character rigging, and is required for anything that will require animations. Creating a rig for a character will change depending on what is required of it, however there are standard setups such as the humanoid rig with a basic set of bones that follow the major points required for animation. The humanoid standard is important, as it allows for easy use of mocap data, which uses a similar set of points when recording. This mocap data can then be retargeted to a model's rig, so long as it follows the same basic rules and structure. For the purposes of this project we will be creating a rig that both follows, and completely breaks the rules of the standard humanoid rig structure. This will result in a character that is able to be completely customised, but also still take advantage of the many built in libraries current engines have associated with the standard humanoid rig, as well as being able to process and retarget mocap data to our character rig.

When a rig is created there are often a series of bones that are purely used as controllers within the 3D program, these do not deform the mesh, but are used to help manipulate deform bones.

The rig we will be creating will utilise bones in three distinct fashions, for the sake of clarity these will be referred to as Animation Bones, Customisation Bones, and Lock Bones. Animation bones are the standard types of bone found in any rigged character, with the mesh weighted to them to allow deformation and animations to be created.

Weighting

For bones to deform and influence the mesh, vertices must be given weight values. Vertices are given values between 0.0 and 1.0 that determine how influenced they are by a given bone. Vertices can be affected by multiple bones, for implementation into a game engine however it is recommended to have no more than four influences on a single bone.

Animation Bones

Animation bones are the standard types of bone found in any rigged character, with the mesh weighted to them to allow deformation and animations to be created. Animation bones require a hierarchy to function correctly in which certain elements are children of others, a good example of this would be the arms being parented to the shoulder. In this scenario when the shoulders rotate so too does the upper arm, forearm and hand in an expected fashion. Without this hierarchy the shoulder would move without the arm, an example of this hierarchy can be seen in Figure 4.

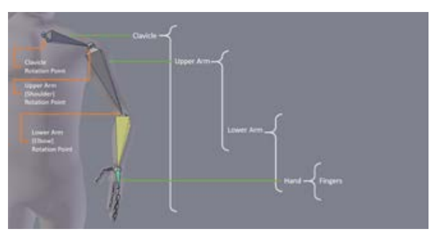

Figure 4: Arm hierarchy

The rig proposed in this project will be different from conventional rigs in that the majority of animation bones will not be weighted to the mesh at all, and contain a hierarchy of bones that are not for animation. It will follow conventional rules (in which elements are required to be parented to animate correctly), whilst adding to this hierarchy to allow for the customisation required. These special bones will be used purely for customisation, yet driven by the animation bones to allow modification of the character. We will refer to these bones as customisation bones.

Customisation Bones

Champions Online's creation system has a robust level of control over the characters physical attributes, allowing for dramatic changes in the avatars body mass. To recreate this feature custom bones will be what we use to customise the characters, allowing us to modify certain areas of the mesh, such as body type or facial details. These bones will modify the mesh through either scaling, offsets, or a combination of scaling and offsets. Customisation bones cannot be animated directly, and as such must be children of an animation bone to allow for animations. These bones will be used and function in two distinct ways, which we will define below.

Weighted Customisers

Weighted customisers are children of animation bones, which allow for the modification of the mesh, but still animate correctly. In this example we can see a Customisation bone that is parented to the upper arm Animation Bone, in this hierarchy the customisation bone will follow and animate with the animation bone. If we scale the customisation bone, it will scale up the bicep area and increase muscle mass. The customisation bone will still follow and animate properly with the animation bone which can be seen below in

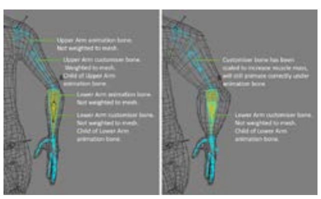

Figure 5: Weighted customisers.

This customisation bone works independent of any other weightings, the upper arm animation bone it is parented to has no weightings associated with the arm mesh, and in this use of the customisation bone is purely used to animate its children, in the given example the upper arm customisation bone.

Weightless Customisers

Weightless customisers will work by being the parent of one, or several animator bones. This is for areas of the body such as the brow which requires customisers and animator bones to be offset together. This is required as without this hierarchy the customiser bones could be offset too far from the animation bones and result in broken or poorly interpolated animations. In the figure below we can see an example of this type of hierarchy.

Figure 6: Weightless customiser bone function.

Lock Bones

Lock bones are used to maintain correct rotations and deformations of the mesh. Without this lock bone the arm will not rotate as expected, an example of this is shown in the figure below.

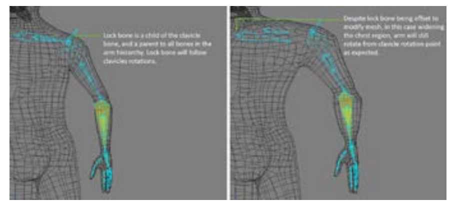

Figure 7: Lock Bone function.

Lock bones are positioned where normally a hierarchy would dictate the rotation of a series of children, where a customiser bone is being used to change position of the said series of children;

Clothing Hair and Aesthetics

Creation of aesthetics for the character are done separately to the base mesh, this includes elements such as clothing, hair, and jewellery. These assets will be created over the base mesh, but as unique objects. These assets will be weighted to bones that best match their use case. These weights will be created through a transfer of data from the base mesh, to best approximate how they should animate. In some cases this will not seamlessly solve the issue of animations, and may require clean up on a case by case basis. Following is an overview of the creation of the different assets.

Clothing

Both of the games investigated for the case study presented the players with a variety of clothing and aesthetic features, in the case of Champions Online, players were also able to alter the colour of clothing. To recreate these features the portions of the body will be duplicated to be used as clothing pieces, for example the chest and arm area of the base mesh will be duplicated out to create a tshirt, or jacket. This duplicated mesh will then be expanded, and given depth but still retain all the vertex data of the original mesh. This means that it will retain the weighting information, and still deform with the rig created, furthermore it will deform identically to the base mesh meaning the clothing will be fitted to the mesh, and not clip or display artifacts.

Hair

Much like the clothing, hair assets will be created after the creation of the base mesh, but will not require the same workflow. The hair meshes will be created to suit the base meshes, and weighted to a bone specifically for their use. The only main consideration here is that they are weighted nicely to the scalp, and parented to the head bone. In this way, if the head bone is scaled up during customisation, the hair will scale in tandem and always fit perfectly.

Aesthetics

General aesthetics may be created after all of these aforementioned tasks have been completed, if time allows. Aesthetics in this context refer to things such as jewellery, earrings or nose piercings, or hats, wrist bands and the like. For most of these kinds of elements, like the hair, unique bones will be created to hold the assets, and parented to bones associated with their placement.

These are scope goals for this project however, and it may not be feasible to expand this far.

Conclusion

Through this project we have validated the need for player interaction in video games, and that enabling them to create their own avatars leads to higher levels of investment and immersion in the experience. This was established through our related works which identified that immersion can be directly related to player investment, and that customisation of their avatar or the game itself can not only add value, but empower disenfranchised users, and open a product to potentially untapped markets.

Our case study confirmed and evaluated systems currently in games, namely Fallout 4 and Champions Online, both of which have character customisation systems that allow for incredible amounts of modification to the avatar. The case study focussed on what modifications were made available, critiqued the limitations, and came to conclusions on what features were of the most value. Ultimately Champions Online proved to give the most freedom in terms of modification, albeit at a lower fidelity, due to its ability to manipulate the body in such a dramatic fashion.

The pipeline this project proposes, whilst implemented and tested with a bipedal humanoid character, can be applied to any type of character design. The principals laid out in each section of said pipeline are generic in terms of software used, or the end result desired. Respectively this means that this pipeline can be utilised for any asset that requires similar kinds of modification, regardless of whether it is a biped or quadruped, or style required such as stylised realism that this project used, or photorealism. The same rules apply regardless of these variables, in regards to how the mesh is created, prepared, and rigged ready for implementation.

Elements that could be improved upon are further study into layering textures, in this project textures are laid upon UV's that cover different areas of the body. An improvement would be application of textures that can be laid anywhere on the model, even across UV seams. Whilst the solution to this may need to be considered through the creation of the asset, much of it would be solved through the implementation and the creation of specialised shaders that were outside the scope of this project. Furthermore, more research could be done upon the implementation and optimisation of the asset into game engines and testing at run time. As well as testing in regards to specifics on levels of player immersion and investment when using such systems.

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