

# THE ART, AESTHETICS, AND MATERIALITY OF THE ARCADE VIDEOGAME INTERFACE

KIERAN NOLAN

A Practice-Included JAMMA Era Arcade Platform Study

A dissertation submitted to the University of Dublin, Trinity College in fulfilment of  
the requirements for the degree of Doctor of Philosophy

Supervisor: Dr. John Dingliana  
November 2019



Trinity College Dublin  
Coláiste na Tríonóide, Baile Átha Cliath  
The University of Dublin

Kieran Nolan: *The Art, Aesthetics, and Materiality of the Arcade Videogame Interface*, A Practice-Included JAMMA Era Arcade Platform Study, © November 2019

## DECLARATION

---

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

I agree to deposit this thesis in the University's open access institutional repository or allow the Library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement.

*Dublin, November 2019*

A handwritten signature in black ink, appearing to read 'Kieran Nolan', written over a horizontal line.

Kieran Nolan



## ABSTRACT

---

This research presents a practice-included platform study of the arcade videogame interface as a self-reflexive art medium. It frames the arcade as both platform and genre, with particular focus on the mid-1980s to late 1990s, the JAMMA era.

Arcade platforms represent a set of technologies designed for consumer level play but traditionally closed off to non-developers as creative mediums. This thesis addresses their nature as aesthetic interfaces, not just for game play, but also as expressive digital materials.

The view of the arcade videogame interface presented encompasses a holistic perspective reaching beyond the communicative link of the audio-visual feedback and input controls, to include the external physical form of the arcade cabinet and associated peripherals, in addition to all communicative links within the system architecture. This expanded view also considers the interface as defined by environment and user context.

In order to reflect the interdisciplinary nature of this research, the methodology draws heavily upon the platform studies approach. This includes technical and historic research alongside case studies of how the system constraints were harnessed to best aesthetic effect. Data sources consulted included archive materials, technical manuals, first hand interviews, and feedback received from exhibitions and online reviews. These findings were complimented by first-hand tacit research of the arcade videogame interface as an artistic medium.

*Control*, *Arcade Operator*, and *VR SuperGun* are a trilogy of interactive self-reflexive meta artefacts that form the material art-practice element of this thesis. These experimental prototypes combine into an experiential, critically reflective composite overview of the arcade interface. Each artefact was created within aesthetic constraints equivalent or approximate to those faced by arcade game creators in the 1980s and 1990s, pragmatically augmented with existing and emergent technologies.

The overall resultant study contributes to understanding of JAMMA era arcade videogames as material and aesthetic forms, and their role as a convergent link across new media art, interface design, game studies, and indie-game development.



## PUBLICATIONS

---

The following outputs were published during my period of research. Certain material and concepts from these publications will necessarily be presented within the body of this work.

### *Journal Articles*

- Nolan, K: **Arcade Operator, an Art Game Experiment about Arcade Repair**. – *Video Game Art Reader*, November 2017, Video Game Art Gallery, Chicago. ISBN: 978-1-38-947045-5.
- Nolan, K: **VRAME: A VR Arcade Cabinet Emulator Prototype**. – *Post Digital Research Newspaper, Digital Aesthetics Research Center*, February 2014, Aarhus University w/ Transmediale, Berlin. ISBN: 87-91810-21-3.

### *Conference Papers*

- Nolan, K: **Bridging Authenticity and Virtualisation in Arcade Videogame Interaction**. – *IEEE Games, Entertainment and Media Conference (GEM) 2018*, August 2018, National University of Ireland Galway. DOI: 10.1109/GEM.2018.8516455. ISBN: 978-1-5386-6304-2.
- Nolan, K: **The Human Machine Art Interface: Arcade Port Aesthetics and Production Practices**. – *Proceedings of the 2018 DiGRA International Conference: The Game is the Message*, July 2018, University of Turin.
- Nolan, K: **Indie Game and New Media Exhibitions as Interface Layers**. – *CHI Play 2017*, October 2017, Pakhuis de Zwijger and Mediamatic, Amsterdam. DOI: 10.1145/3130859.3131430. ISBN: 978-1-4503-5111-9 [pp. 37-45].
- Nolan, K: **Arcade Videogame Interface Aesthetics**. – *ISEA / International Symposium on Electronic Art 2016 Cultural R>evolution*, Hong Kong, May 2016, City University of Hong Kong. ISBN: 9789624423976 [pp. 128-134].

### *Invited Talks*

- Nolan, K: **Arcade Videogames as Aesthetic Interfaces and Self-Reflexive Research Artefacts**. – *SHU Cultural, Communication*

and Computing Research Institute (C3RI), November 2019, Sheffield Hallam University.

- Nolan, K: **Arcade Archive Authenticity: Schematics, Spare Parts, and Retrofits.** – *Collaborative Game Histories*, October 2019, Finnish Museum of Games, Tampere.
- Nolan, K: **Arcade Game Design Adaptations: 1980s and 1990s Japanese Coin-Op Conversions and Pseudo Sequels for Western Computer Platforms.** – *Replaying Japan 2019*, August 2019, Ritsumeikan University, Kyoto.
- Nolan, K: **Arcade Game Materiality: VR SuperGun.** – *ELO2019, The Electronic Literature Organization Conference & Media Arts Festival*, July 2019, University College Cork.
- Nolan, K: **Arcade Materiality Across Analog and Digital Space.** – *Sites of Gaming and Arcade Situations, International Conference on the Cultural History of (Video)Game Arcades*, June 2019, Carl von Ossietzky University of Oldenburg.
- Nolan, K: **Arcade Videogame Materiality: VR SuperGun.** – *The State of Play*, May 2019, Technological University Dublin, City Campus.
- Nolan, K: **Game Aesthetics: Platform Constraints + Creative Affordances.** – *Game Talk #4*, April 2019, MA in Game Design, IULM University of Milan.
- Nolan, K: **Indie Game and New Media Exhibitions as Interface Layers.** – *Irish HCI Conference 2018*, November 2018, University of Limerick.
- Nolan, K: **JAMMA Arcade Platform: Interface Constraints and Aesthetic Affordances.** – *Replaying Japan 2018*, August 2018, National Videogame Arcade, Nottingham.
- Nolan, K: **Arcade Videogame Platform Art, Materiality, and Preservation Tactics.** – *Game Studies Seminar, Centre for Computer Games Research*, November 2017, IT University of Copenhagen.
- Nolan, K: **Copyright Circumventions, Gameplay Modifications, and Platform Augmentations of Classic Coin-Operated Video Games.** – *CEEGS / Central and Eastern European Game Studies Conference 2017*, September 2017, Univerzita sv. Cyrila a Metoda, Trnava.
- Nolan, K: **Arcade Video Game Conversion Processes and Aesthetics, Workshop Paper.** – *CEEGS / Central and Eastern European Game Studies Conference 2016*, October 2016, Centre for the Meetings of Culture, Lublin.



- Nolan, K: **Indie Games as Art Research**. – *The State of Play 2016*, July 2016, Dublin Institute of Technology.
- Nolan, K: **Arcade Videogame Art**. – *Playing the Game*, May 2016, IED Istituto Europeo di Design, Milan.
- Nolan, K: **Video Games as Self-Reflexive New Media Research Artefacts**. – *Research Leaders Seminar Series*, October 2015, Dundalk Institute of Technology.
- Nolan, K: **Open Source Hardware Technologies in Art, Design, Interaction, & Learning and Teaching**. – *MAKE Symposium*, March 2014, CIT Crawford School of Art & Design, Cork.
- Nolan, K: **Panel Talk Participant: Post Digital Research**. – *Transmediale*, February 2014, Berlin.

### *Exhibitions*

- Nolan, K: **VR SuperGun**. – *Amsterdam JSNation Conference 2019*, June 2019, Amsterdam.
- Nolan, K: **VR SuperGun**. – *3DCamp Dublin AR / VR Meetup*, February 2019, Workday, Dublin.
- Nolan, K: **Control**. – *ISEA / International Symposium on Electronic Art 2016 Cultural R>evolution*, Hong Kong, May 2016, HK Polytechnic University.
- Nolan, K: **Control**. – *Game on! El arte en juego*, November 2015, San Martín Cultural Center, Buenos Aires.
- Nolan, K: **Control**. – *Out Of Index 2015 offline showcase*, July 2015, Google Campus Seoul.
- Nolan, K: **Control**. – *Materiality*, University Gallery, May and June 2015, National University of Ireland Galway.
- Nolan, K: **Control**. – *The Blank Arcade*, DiGRA Conference 2015, May 2015, Lunebürg.
- Nolan, K: **Control**. – *Art.CHI 2015*, ACM SIGCHI 2015, April 2015, Seoul.
- Nolan, K: **Control**. – *Vector 2015*, February and March 2015, Interaccess Gallery, Toronto.
- Nolan, K: **Control**. – *EGX 2014 Leftfield Collection*, September 2014, Earls Court Exhibition Centre, London.
- Nolan, K: **Control (Concept Cartridge Artwork)**. – *My Famicase Exhibition 2014*, May 2014, METEOR, Tokyo.

- Nolan, K: **Control**. – *A MAZE. 3rd International Independent Video Games Festival*, April 2014, Berlin.

#### *Poster*

- Nolan, K: **Control: Critical Play Through Interface Constraints**. – *Irish HCI Conference 2013*, June 2013, Casala Research Centre, Dundalk Institute of Technology.

#### *Radio Interview*

- Nolan, K: **Built to Play 55: Interface The Machine**. – *Built to Play*, March 2015, CJRU 1280AM, Ryerson University, Toronto.

#### *Doctoral Consortium*

- Nolan, K: **Arcade Videogame Interface Art, Aesthetics and Materiality**. – *DiGRA and FDG 2016 Conference*, August 2016, University of Abertay, Dundee.

#### *Honours*

- Nolan, K: **VR SuperGun (Winner, Technical Achievement)**. – *Imirt Irish Game Awards*, September 2019, Dublin.
- Nolan, K: **Early Career Researcher, Creative Arts, Humanities and Social Sciences (Awardee)**. – *President's Awards for Research Excellence*, May 2017, Dundalk Institute of Technology.
- Nolan, K: **Control (Finalist)**. – *A MAZE. 3rd International Independent Video Games Festival*, April 2014, Berlin.

## ACKNOWLEDGEMENTS

---

I'm very lucky in that I have a lot of people to thank, so many that attempting to list everyone will inevitably omit someone by accident, so I will keep this relatively short.

During this research journey I've had the privilege of linking up with a fantastic community of practice. If at some point you've expressed an interest in my research, peer reviewed my work, or helped facilitate me at a conference talk or exhibition, then please consider yourself among the list. I hope we cross paths again soon.

I must give particular thanks to John Dingliana for all his help and guidance through the learning journey towards completing this thesis. Thank you for responding to my application and taking me on as a student. Also many thanks to Matthew Causey and the Digital Arts and Humanities PhD cohort.

Thank you to the HR and Research offices at Dundalk Institute of Technology for helping fund my research, and to my DkIT colleagues across the institute for your moral support and for helping me navigate the logistical hurdles involved in mixing a full time job alongside study.

I also gratefully acknowledge those who taught me at my alma maters, from the Design Department at Letterkenny Institute of Technology, and the Interaction Design Centre at the University of Limerick.

This work is dedicated to my parents Mary and Seamus, and my siblings Maria and Joseph.



## CONTENTS

---

<b>I</b>	<b>INTRODUCTION</b>	<b>1</b>
1	INTRODUCTION	3
1.1	Formulation of Research Question . . . . .	3
1.2	Summary of Chapters . . . . .	4
2	METHODOLOGY	7
2.1	Platform Studies . . . . .	7
2.2	Media Archaeology . . . . .	8
2.3	Art-Based Research . . . . .	9
2.4	Games as Art . . . . .	10
2.5	A Game Studies and Media Art Hybrid . . . . .	11
2.6	Implementation . . . . .	12
2.7	Arcade Material as Toolset . . . . .	13
2.7.1	Era-Equivalent Audiovisual Constraints . . . . .	14
2.7.2	Production Constraints . . . . .	15
2.8	The Experiential Composite . . . . .	16
2.9	Evaluation Strategy . . . . .	17
<b>II</b>	<b>ARCADE INTERFACE ANATOMY</b>	<b>19</b>
3	ARCADE VIDEOGAME INTERFACE AESTHETICS	21
3.1	An Arcade Interface Taxonomy . . . . .	21
3.1.1	Input and Feedback Mechanisms . . . . .	22
3.1.2	Static and Dynamic Interfaces . . . . .	23
3.1.3	Interface Convergence . . . . .	24
3.1.4	Interface Accessibility and Gameplay Challenge	24
3.1.5	Game Aesthetics and the Experiential . . . . .	25
3.2	Building an Interface for Play . . . . .	25
3.2.1	Videogame Interface Emergence . . . . .	26
3.2.2	Interface Functionality vs Playability . . . . .	27
3.2.3	Utilitarian Interface Layers . . . . .	28
3.3	The Emulator as Interface . . . . .	28
3.4	Bit Rot, Scanlines, and Glitch Art . . . . .	29
3.5	Emulation, ROM Hacks, and Platform Enhancements .	30
3.5.1	Videogame Music Interfaces . . . . .	32
3.6	Interface Aesthetics and Authenticity . . . . .	36
3.7	Conclusions . . . . .	37
4	JAMMA: ERA, INTERFACE, PLATFORM, AESTHETIC	39
4.1	JAMMA the Trade Organisation . . . . .	39
4.2	JAMMA Standard: A Hardware-to-Hardware Interface	40
4.3	JAMMA Standard: Development Timeline . . . . .	42
4.4	The JAMMA Era . . . . .	44
4.5	JAMMA as a Platform . . . . .	44
4.6	JAMMA Technical Specifications . . . . .	45

4.6.1	JAMMA Augmentations . . . . .	46
4.7	JAMMA Case Study: Street Fighter II . . . . .	48
4.7.1	Street Fighter II JAMMA bootlegs . . . . .	48
4.7.2	Capcom CPS Changer System . . . . .	49
4.8	The SuperGun Consolised JAMMA Setup . . . . .	49
4.8.1	SuperGun Terminology . . . . .	49
4.8.2	SuperGun Technical . . . . .	50
4.8.3	Scanline Generators and RGB Amps . . . . .	50
4.9	Console Timer Boards . . . . .	51
4.10	ARM-Based Multi-Game Boards . . . . .	51
4.11	The SNK Neo Geo AES and MVS systems . . . . .	52
4.12	Early PC-Based JAMMA Hardware . . . . .	52
4.13	Single-Board Computer JAMMA Systems . . . . .	53
4.14	PC-Based Modern Indie JAMMA Arcade . . . . .	54
4.15	Post-JAMMA: JVS (aka JAMMA 2) . . . . .	55
4.16	The JAMMA Aesthetic . . . . .	56
4.17	Conclusions . . . . .	57
5	ARCADE: PLATFORM, MATERIAL, GENRE . . . . .	59
5.1	Arcade Conversions and Computer Born Arcade . . . . .	59
5.2	Home Computer to Arcade Platform . . . . .	61
5.3	Arcade to Home Conversion Creative Practices . . . . .	62
5.3.1	Magazine Advertising: Arcade Authenticity and Approximation . . . . .	65
5.3.2	1990s Game Advertising as Inadvertent Game Art . . . . .	67
5.3.3	Forgotten Worlds (1989) . . . . .	69
5.3.4	Rainbow Islands (1989) . . . . .	71
5.3.5	Midnight Resistance (1990) . . . . .	74
5.3.6	Conversion Augmentations . . . . .	75
5.4	Conclusions . . . . .	77
	III ARCADE SELF-REFLEXIVITY . . . . .	81
6	ARTEFACT A: CONTROL . . . . .	83
6.1	Background Context . . . . .	83
6.1.1	Physical Constraints in Arcade Gaming . . . . .	84
6.1.2	Game Controller Categories . . . . .	84
6.1.3	Affordances and Constraints in Gaming . . . . .	85
6.1.4	The Controller as Game Focus . . . . .	85
6.1.5	Control Schemes as Constraints . . . . .	86
6.1.6	Porting Arcade Control Schemes across Platforms . . . . .	89
6.1.7	Joysticks to Joypads . . . . .	90
6.2	Process and Materials . . . . .	92
6.2.1	Initial Concepts . . . . .	92
6.3	Authoring Environment . . . . .	93
6.3.1	Visual and Sonic Palette Constraints . . . . .	94
6.3.2	Soundtrack and Audio Effects . . . . .	95
6.3.3	The Assembly and Build Process . . . . .	96

6.3.4	Control Description . . . . .	99
6.3.5	Control Walkthrough . . . . .	101
6.4	Dissemination, Reaction, and Evaluation . . . . .	104
6.4.1	Pre-Release . . . . .	105
6.4.2	Online Launch and Indie Game Press Reception . . . . .	105
6.4.3	Gameplay Video Playthroughs as User Feedback . . . . .	106
6.4.4	Video Review Findings . . . . .	107
6.4.5	Competition Jury Feedback . . . . .	110
6.4.6	The Exhibition Environment as an Interface Layer . . . . .	111
6.4.7	A MAZE. / Berlin . . . . .	111
6.4.8	Vector Festival, Toronto . . . . .	113
6.4.9	Materiality, Galway . . . . .	115
6.4.10	Art.CHI, Seoul . . . . .	116
6.4.11	Out Of Index, Seoul . . . . .	117
6.4.12	Control at METEOR Tokyo, 2014 . . . . .	120
6.5	Further Implementation Possibilities . . . . .	120
6.6	Conclusions . . . . .	122
7	ARTEFACT B: ARCADE OPERATOR . . . . .	125
7.1	Introduction . . . . .	125
7.1.1	The Arcade, Critical Play, Self-Reflexivity, and the Metagame . . . . .	126
7.1.2	Interface Context . . . . .	126
7.1.3	Developer Level Context . . . . .	127
7.1.4	Interface Context: Player, Operator, Artist . . . . .	127
7.1.5	Arcade in Arcade . . . . .	128
7.1.6	Arcade as Pseudo-Simulation . . . . .	129
7.1.7	Repair in Arcade Games . . . . .	130
7.1.8	Design Constraint Considerations . . . . .	130
7.2	Production Toolkit . . . . .	132
7.2.1	Concept Origins . . . . .	132
7.2.2	Initial Sketches . . . . .	132
7.2.3	Character Design . . . . .	133
7.2.4	Typography . . . . .	133
7.3	Game Environment Design . . . . .	134
7.3.1	Side Scrolling Brawler Perspective . . . . .	135
7.3.2	Environment Implementation . . . . .	136
7.3.3	Featured Arcade Coin-Ops . . . . .	137
7.4	Soundtrack and Audio Effects . . . . .	138
7.5	Production Timeline and Online Distribution . . . . .	141
7.6	Interaction Walkthrough . . . . .	142
7.6.1	Boot Sequence and Title Screen . . . . .	142
7.6.2	Level Introduction . . . . .	142
7.6.3	Visual Interface . . . . .	143
7.6.4	In-Game Arcade Repair . . . . .	145
7.7	Alternative Production Approaches . . . . .	146
7.8	Conclusions . . . . .	146

8	ARTEFACT C: VR SUPERGUN	149
8.1	The Physiology of an Arcade Cabinet . . . . .	150
8.2	Emulation as Platform Augmentation . . . . .	151
8.3	Arcade Materiality in New Media Art . . . . .	152
8.3.1	OutRun . . . . .	152
8.3.2	Colorless, Odorless and Tasteless . . . . .	152
8.3.3	Protopixel HARDcade . . . . .	153
8.3.4	Arcade Concrete . . . . .	153
8.4	Arcade Materiality in Digital Game Space . . . . .	153
8.4.1	Namco Museum Volume 1 . . . . .	154
8.4.2	Shenmue's You Arcade . . . . .	155
8.4.3	New Retro Arcade: Neon . . . . .	156
8.4.4	EmuVR . . . . .	157
8.5	Framing the 4:3 Aspect Ratio: Peripheral Vision . . . . .	157
8.5.1	Sega 3D Classics . . . . .	158
8.5.2	Custom MAME themes . . . . .	158
8.6	Interface Distance and Ritual . . . . .	159
8.6.1	Environmental Interaction Memories . . . . .	160
8.7	Digital Preservation: Functionality vs. Aesthetics . . . . .	161
8.7.1	ROM Materiality . . . . .	162
8.7.2	Emulation and Tangibility . . . . .	163
8.8	Hardware and Software Development Process . . . . .	164
8.8.1	Modular Code through Web Frameworks . . . . .	165
8.8.2	Browser to JAMMA Hardware Interface . . . . .	165
8.9	Virtual Arcade Construction . . . . .	166
8.9.1	Grid Environment . . . . .	168
8.9.2	Virtual CRT Monitor Design Process . . . . .	168
8.9.3	Vectors to Voxels . . . . .	169
8.10	Network Play Prototype . . . . .	169
8.10.1	Remote Access Implementation . . . . .	169
8.11	Interactive Prototype Overview . . . . .	170
8.12	Future Development Paths . . . . .	172
8.13	Conclusions . . . . .	174
IV	CONCLUSION	175
9	CONCLUSION	177
9.1	Contributions . . . . .	177
9.1.1	Game Studies Contribution . . . . .	177
9.1.2	Interface Aesthetics Contribution . . . . .	178
9.1.3	Media Art Contribution . . . . .	179
9.1.4	Game Preservation Contribution . . . . .	180
9.1.5	Technical Contribution . . . . .	180
9.1.6	Methodological Contribution . . . . .	180
9.2	Limitations . . . . .	181
9.3	Research Practice Tangibility . . . . .	182
9.4	Future Trajectories . . . . .	182
9.5	JAMMA Era Arcade Legacy . . . . .	183



V	APPENDIX	185
A	ARTEFACT WEBLINKS AND DOWNLOADS	187
A.1	Artefact A: Control . . . . .	187
A.2	Artefact B: Arcade Operator . . . . .	187
A.3	Artefact C: VR SuperGun . . . . .	188
B	INTERVIEW	189
	BIBLIOGRAPHY	201
	LUDOGRAPHY	215

## LIST OF FIGURES

Figure 1	Sega Digitizer and Taito TAECOM-11 joystick.	14
Figure 2	Arcade Interface Meta Trilogy. . . . .	16
Figure 3	JAMMA and JVS introductory periods. . . . .	41
Figure 4	JAMMA organisation meetings. . . . .	43
Figure 5	JAMMA Edge Connector Technical Schematic.	44
Figure 6	JAMMA compatible PCB and wiring harness.	45
Figure 7	JAMMA compatible SuperGun devices. . . . .	51
Figure 8	Taito’s Wolf System Hardware. . . . .	53
Figure 9	NAVE PC to JAMMA and custom LEDs. . . . .	54
Figure 10	<i>Skycursor</i> conversion kit and cabinet. . . . .	55
Figure 11	<i>Skycursor</i> in-game screenshot. . . . .	56
Figure 12	<i>Blasteroids</i> and <i>Operation Wolf</i> advertisements.	66
Figure 13	<i>Operation Wolf</i> , arcade original and C64 version.	67
Figure 14	<i>Ghosts ‘N Goblins</i> magazine advertisement. . .	68
Figure 15	<i>Forgotten Worlds</i> arcade vs Amiga. . . . .	70
Figure 16	<i>Forgotten Worlds</i> shop stage versions. . . . .	71
Figure 17	<i>Rainbow Islands</i> character animation frames. . .	72
Figure 18	Atari ST and Amstrad CPC <i>Rainbow Islands</i> . . .	73
Figure 19	<i>Midnight Resistance</i> platform comparisons. . . .	75
Figure 20	<i>Midnight Resistance</i> magazine advertisement. .	76
Figure 21	Amiga and Atari ST <i>Snow Bros</i> animation. . . .	77
Figure 22	Amiga <i>Mercs</i> Clown’s Nose weapon. . . . .	78
Figure 23	The ZX Spectrum cassette loader <i>Street Fighter II</i> .	79
Figure 24	Hudson Soft <i>Shooting Watch</i> . . . . .	86
Figure 25	NAVE control panel in use. . . . .	87
Figure 26	<i>Final Fight</i> control panel install documents. . .	87
Figure 27	Sega Dreamcast enabled control panel. . . . .	88
Figure 28	<i>Control</i> early concept sketches . . . . .	92
Figure 29	Anthropomorphic controller game characters.	93
Figure 30	Stencyl authoring environment. . . . .	93
Figure 31	Code blocks in Stencyl. . . . .	94
Figure 32	Gamepad concept sketches . . . . .	96
Figure 33	Early <i>Control</i> joypad and hand concept. . . . .	96
Figure 34	<i>Control</i> tileset graphics tests. . . . .	97
Figure 35	Early controller graphics tests. . . . .	97
Figure 36	OctoPad development and implementation. . .	98
Figure 37	<i>Control</i> hand development concepts. . . . .	98
Figure 38	<i>Control</i> hand collisions test. . . . .	99
Figure 39	<i>Control</i> intro, title, and get ready screens. . . .	101
Figure 40	<i>Control</i> levels 1 to 4. . . . .	102
Figure 41	<i>Control</i> levels 5 to 8. . . . .	103

Figure 42	<i>Control</i> levels 9 and 10. . . . .	103
Figure 43	<i>Control</i> level clear and game over screens. . . . .	104
Figure 44	<i>Control</i> congratulations screen 1 of 4. . . . .	104
Figure 45	<i>Control</i> in-situ at A MAZE. / Berlin. . . . .	112
Figure 46	Interacting with <i>Control</i> at A. Maze / Berlin. . . . .	113
Figure 47	Standing level <i>Control</i> install at Vector Festival. . . . .	114
Figure 48	<i>Control</i> gameplay session at Vector Festival. . . . .	115
Figure 49	A player completes <i>Control</i> at Vector Festival. . . . .	115
Figure 50	<i>Control</i> at Materiality, NUI Galway. . . . .	116
Figure 51	A visitor engaging with <i>Control</i> at Materiality. . . . .	117
Figure 52	<i>Control</i> at Out Of Index, Seoul. . . . .	118
Figure 53	The audience at Out Of Index watching <i>Control</i> . . . . .	119
Figure 54	<i>Control</i> My Famicase artwork. . . . .	120
Figure 55	<i>Golden Axe</i> end sequence. . . . .	129
Figure 56	<i>After Burner II</i> attract mode. . . . .	129
Figure 57	Initial <i>Arcade Operator</i> concept renderings. . . . .	133
Figure 58	<i>Arcade Operator</i> sprite frame selection. . . . .	134
Figure 59	<i>Double Dragon</i> , level 1. . . . .	135
Figure 60	<i>Golden Axe</i> , levels 1 to 3. . . . .	136
Figure 61	<i>Robocop 2</i> , level 2. . . . .	137
Figure 62	<i>Arcade Operator</i> test level layout. . . . .	137
Figure 63	Using paper markers to position 3D models. . . . .	138
Figure 64	Game boot up screens. . . . .	142
Figure 65	<i>Arcade Operator</i> title screen. . . . .	143
Figure 66	<i>Arcade Operator</i> repair guide. . . . .	143
Figure 67	<i>Arcade Operator</i> in-game view. . . . .	144
Figure 68	<i>Arcade Operator</i> repair feedback graphics. . . . .	145
Figure 69	<i>SuperGun</i> VR prototype. . . . .	149
Figure 70	VR <i>SuperGun</i> front and back views. . . . .	150
Figure 71	<i>Namco Museum Volume 1</i> . on PlayStation. . . . .	154
Figure 72	<i>Galaga</i> in <i>Namco Museum Volume 1</i> . . . . .	155
Figure 73	<i>Shenmue's</i> You Arcade. . . . .	156
Figure 74	VR environments as emulator front-ends. . . . .	157
Figure 75	<i>Thunder Blade</i> for arcade and Nintendo 3DS. . . . .	158
Figure 76	<i>Wonderboy</i> MAME comparison. . . . .	159
Figure 77	Gandhi's Salt March in <i>Second Life</i> . . . . .	160
Figure 78	<i>Space Invaders</i> and Amiga 1000 preservation. . . . .	162
Figure 79	VR <i>SuperGun</i> latency test A. . . . .	165
Figure 80	Arduino MEGA to JAMMAhelper circuit. . . . .	166
Figure 81	VR <i>SuperGun</i> control circuit. . . . .	167
Figure 82	Modelling and assembling the virtual coin-op. . . . .	168
Figure 83	Voxel modelled arcade components. . . . .	169
Figure 84	VR <i>SuperGun</i> desktop setup. . . . .	170
Figure 85	VR <i>SuperGun</i> hardware diagram. . . . .	171
Figure 86	Arduino to JAMMA key map. . . . .	171
Figure 87	<i>Altered Beast</i> streamed to the HTML Canvas. . . . .	172

Figure 88	The VR <i>SuperGun</i> using a monoscopic 3D display.	173
-----------	---	-----

## LIST OF TABLES

---

Table 1	JAMMA Pinout . . . . .	47
Table 2	Platform technical comparison chart. . . . .	63
Table 3	<i>Control</i> level summary . . . . .	99
Table 4	<i>Arcade Operator</i> soundtrack . . . . .	141

## ACRONYMS

---

6502	The MOS Technology 6502, an 8-bit microprocessor
68000	The Motorola 68000 series of 16/32-bit CPUs
AES	Advanced Entertainment System home console by SNK
BIOS	Basic input/output system. Firmware used to initialise booting process
CPS-1	Capcom Play System 1
CRT	Cathode Ray Tube
EPROM	Erasable Programmable Read-Only Memory
GPU	Graphics Processor Unit
IFF	Interchange File Format
JAIA	Japan Amusement Industry Association
JAMMA	(Organisation, 1981 to 31st March 2012) The Japan Amusement Machine Manufacturers Association
JAMMA	(Organisation, 1st April 2012 to 31st March 2018) The Japan Amusement Machine and Marketing Association, Inc
JAMMA	(Standard) A PCB connector and wiring standard introduced by the JAMMA consortium in 1985
JVS	Japan Video Standard, also known as JAMMA 2
M-92	An arcade system board by Irem
MAME	Multiple Arcade Machine Emulator
MIDI	Musical Instrument Digital Interface
MVS	Multi-Video System arcade by SNK
PCB	Printed Circuit Board
PDS	Programmers Development System, a multi platform developer system by Andy Glaister
ROM	Ready-Only Memory
STOS	STOS Basic, a programming language for the Atari ST
Z80	The Zilog Z80 CPU, an 8-bit microprocessor

Part I

INTRODUCTION





## INTRODUCTION

---

### 1.1 FORMULATION OF RESEARCH QUESTION

This research presents a platform study from an artist-researcher point of view of the arcade videogame interface. The study frames the arcade videogame as both platform and genre, investigating the aesthetics, materiality, and connective properties of its interface through a bridging of technical, historic, and creative inquiry.

It asks 'How can the arcade interface act as a self-reflexive art object to examine its own material and aesthetic properties?' However, in order to answer this question, it is necessary to define a number of parameters that will establish the scope of the research.

To focus the breadth of this enquiry, the thesis mainly focuses on the Japan Amusement Machine and Marketing Association's JAMMA arcade standard and its era, from its inception in 1985 to the late 1990s, a point at which home and arcade videogame platforms reached technical and aesthetic parity. The term arcade is used to signify both platform and genre, the situated space of the arcade, and also the arcade as a post-digital aesthetic existing independently from digital media.

The view of the arcade videogame interface explored encompasses a holistic perspective reaching beyond the communicative link of the audio-visual feedback and input controls, to include a wider view including the external physical form of the arcade cabinet and associated peripherals, in addition to the internal hardware makeup of the arcade interface. This expanded view also considers the interface as defined by environment and user context.

By doing so it explores not only the consumer, operator, and developer level interpretations of the interface, but also that of the artist interfacing with the material constraints of the arcade gaming medium, whether through ground-up development or the reappropriation of existing read-only systems as creative canvases.

The material thesis consists of a trilogy of interactive artefacts that combine to form a composite, critically reflective picture of the arcade interface in its totality. As a body of work the artefacts address key aspects of the arcade interface, including aesthetics, materiality,

constraints, embodiment, agency, accessibility, environment, and platform preservation. These sub-themes are distributed across three distinct thematic categories that together form a composite conceptual picture of the arcade videogame form (see [Chapter 2](#)).

A critical element of reflective understanding is gained from working in media constraints equivalent or approximate to those faced by arcade game creators in the mid-1980s and 1990s, while augmenting these pragmatically with existing and emergent technologies, with the aim of realising original contributions to knowledge through the experiential composite of the Arcade Interface Meta Trilogy.

The overall thesis makes original contributions back to the fields that it draws upon, presenting an overview of JAMMA era arcade videogames as creative and aesthetic digital mediums. Its practice-based outputs further reinforce the convergent links between new media art, interface design, game studies, and indie-game development.

## 1.2 SUMMARY OF CHAPTERS

[Chapter 1](#) introduces the thesis, explaining the background and rationale for the study as a practice-informed and theory backed research study of mid-1980s to late 1990s (JAMMA era) arcade videogame aesthetics from the angles of platform, genre, material, and interaction. It asks the research question ‘How can the arcade interface act as a self-reflexive art object to examine its own material and aesthetic properties?’ Arcade is introduced as a fluid term, blurring the lines between platform, genre, and gameplay aesthetic. Aesthetics in the videogame context includes not just in terms of audiovisual fidelity but also gameplay experience through interaction with the given system as a holistic unit encompassing control, feedback, the inner diegetic space of the game world, alongside the physical interaction space of the hardware platform and its situated environment.

[Chapter 2](#) details the cross-disciplinary methodology of this thesis, borrowing largely from the platform studies approach, where a computational platform is examined from historic and technical angles, alongside case studies of how the system’s constraints were creatively harnessed to the best functional and aesthetic affordances. It also bridges the theory and practice sides of this study, introducing the Arcade Interface Meta Trilogy, a series of game-based experimental artefacts that combine together to form an experiential composite overview of the arcade video game interface. Situated in the spaces of indie games and media art, these self-reflexive meta artefacts use

the arcade interface to explore issues surrounding its connective, aesthetic, and material properties. It considers the aesthetic properties of the toolsets and production practices that shaped JAMMA era arcade game developers. At practitioner level, the material constraints used in constructing these pieces were kept aesthetically approximate to those used by arcade game developers in the 1980s and 1990s, using tile-based game engines, pixel art, chiptune audio, and low resolution 3D polygon graphics.

[Chapter 3](#) delivers a primer on the aesthetic and connective properties of arcade videogame interfaces. It considers the arcade videogame interface as a communicative and creative link that extends beyond play orientated input and feedback mechanisms. With the correct emulation and homebrew tools, videogame platforms that were originally designed as consumer only devices become malleable forms that can be interfaced at artist and developer levels, allowing previously closed hardware and software systems to function as reconfigurable digital materials.

[Chapter 4](#) is focussed on the JAMMA arcade standard, exploring the JAMMA wiring standards origins, technical specifications, while providing an overview of JAMMA interface implementations. It also considers JAMMA as a platform and aesthetic. As a hardware specification it places a uniform set of baseline constraints on the audio-visual and interaction aesthetics of JAMMA compliant arcade game systems.

The fluidity of the term arcade as it crosses over between platform, material and genre is further explored in [Chapter 5](#). The blurred boundaries of hardware, software, and interaction in terms of arcade games originating in the arcade converted to home systems, computer-born arcade titles, and the crossover between arcade and home hardware and software are explored. A number of case studies of arcade to home computer game conversions from the late 1980s and early 1990s are compared and contrasted in order to understand the remediation process of arcade conversions as created through the human-machine art interface of their development teams.

[Chapter 6](#) details the background, development process, and findings of *Control*, an experimental meta game about arcade interface constraints. Instead of making the interface seamless and invisible, *Control* interfaces the user with a downsampled representation of their hand through the basic arcade control scheme of eight directions and one action button. *Control* has ten levels, the first nine of which take the user through an evolution of game controller complexity, with level 10, the speculative OctoPad controller prototype, embody-

ing a possible form for the future evolution of game controllers if left to evolve as organic forms. Engaging with *Control* exposes the resolution divide experienced when interacting with digital space, placing users in the situation of having limited manual dexterity while facing the challenge of engaging with complex (virtual) game controllers through their virtual hand. Chapter 6 also details *Control*'s arcade interface as defined by curatorial choices at a series of public exhibitions in media art and indie game spaces.

Chapter 7 documents the second artefact of the trilogy material thesis, detailing the rationale, development, and gameplay experience of *Arcade Operator*, an art game that explores the arcade interface as defined by user context. Drawing upon historic documentation, field research, and first hand interviews it provides an experiment in articulating the non-play level of interfacing involved in repairing and maintaining arcade videogame platforms through the language of the side scrolling arcade brawler sub-genre. The conceptual and practical challenges faced while developing *Arcade Operator* are discussed, alongside the meta experience articulated through the artefact.

Chapter 8 provides an overview of the *VR SuperGun*, a response to the material temporality of arcade videogame hardware and the disappearance of arcade videogames from public use into private collections and museums. *VR SuperGun* extends the JAMMA hardware standard into networked virtual space, allowing netplay of physical arcade game boards both locally and across the internet, reconstituting the physical form of the arcade cabinet in 3D virtual reality space. As a technical solution it offers a trade off between the immediacy and accessibility of emulation, and the tangible and subjective authenticity experienced through using original arcade hardware. In the context of game art and media art it uses the material of the JAMMA hardware interface to explore the boundaries of interfacing with the complete arcade machine through remote digital means, providing a meditation on the physicality of hardware both in its form and situated environment, alongside the representational experience of these aspects through software.

Chapter 9 concludes the thesis. It reflects on all preceding chapters, considering the totality of research findings, including obstacles and limitations encountered, while presenting possible future trajectories for branching off from the components of this interdisciplinary research study.

## METHODOLOGY

---

In order to answer the research question of ‘How can the arcade interface act as a self-reflexive art object to examine its own material and aesthetic properties?’ the methodology for this study employs a multidisciplinary combination of strategies, including platform studies, media archaeology, and critical design. It is a practice-included approach, where the ‘material thesis’ [155, p. 16] of the artefacts expound and reinforce the content of the written PhD dissertation.

As a research study originating from the digital arts domain, the most immediate task, aside from establishing the research topic, was to find a suitable working methodology. There is no set template for practice-included research of digital media platforms as aesthetic materials, so a suitable synthesis of methods had to be arrived at. Anthony Dunne’s 1999 critical design PhD provided an exemplar of doctoral research integrating art and design practice:

“In Dunne’s case, the electronic object produced as the studio section of the doctorate is still “design,” but in the sense of a “material thesis” in which the object itself becomes a physical critique” [155, p. 16].

The thesis mainly employs qualitative research elements. It reflects the artist’s point of view through the collation and reflective analysis of insights uncovered through the tacit process of creation within constraints, in addition to those of the users as gathered through peer feedback. Each of the three artefacts are grounded through background research communicated through the written thesis from relevant historical, technical, philosophical, and aesthetic fields.

### 2.1 PLATFORM STUDIES

At the outset of this thesis in 2012, the platform studies approach set out in 2009’s *Racing the Beam* [127] was identified as both closely aligned with and adaptable to the interdisciplinary and practice-included task set out by the thesis to frame the arcade interface as a metareferential series of game-based artefacts.

The field of platform studies is defined as “the investigation of underlying computer systems and how they enable, constrain, shape,

and support the creative work that is done on them" [127, p. vii].

*Racing the Beam* [127] provides an in depth study of the Atari 2600 videogame console (1976), describing its origins, technical specifications and cultural impact. In particular it focusses on the constraints of the platform and the creative steps that engineers and programmers took to push the machine beyond its capabilities, for example using the phosphor blur of cathode ray tube televisions to mix colours and compensate for sprite flicker rates. Similarly, *The Future was Here* [113] explores how Amiga game developers studied their medium to the point that they could exploit hardware bugs and machine level processes to expand the creative and aesthetic properties of the platform.

Platforms are defined by Monfort and Bogost as "the lower computational levels, the platforms (hardware system, operating system, virtual machines) on which code runs", with platform studies having with three main features:

"A focus on a single platform or a closely related family of platforms.

Technical rigor and in-depth investigation of how computing technologies work.

An awareness of and discussion of how computing platforms exist in culture and society" [127, p. vii-viii].

This study takes a platform studies infused angle on JAMMA era arcade games, exploring their technical, historical, and creative affordances, alongside their materiality as platform, genre, and as digital mediums<sup>1</sup>.

<sup>1</sup> It is important to note that adoption of platform studies as a central pillar of this methodology does not imply endorsement from its originators, and is done in a spirit of scholarship and respect.

## 2.2 MEDIA ARCHAEOLOGY

Apperley and Parikka (2015) point out how the previous definition has been left deliberately open, and highlight how the historic and material aspects of platform studies can benefit from media archaeology approaches, aligning with the take on platform studies explored through this thesis [12]. This includes research of paratexts to gain greater understanding of a platform's reception by users and its place in society [41, p. 21] [165, p. 94-117]. This method is employed throughout this thesis, for example in Chapter 5, through analysis of archived developer interviews and advertising features from 1990s videogame magazine. Chapter 6 incorporates feedback from video playthroughs, game festival juries, and online press reviews.

Another area of media archaeology put forward by Apperley and Parikka as complimentary to platform studies is that of direct material exploration through critical artistic practice.

"By exposing the seams, critical design and art practices indicate possible pathways for interrogating the uniformity and (im)mutability of the platform. Opening the platform suggests new strategies for platform studies which connect it to critical practices in new media arts and existing practices of hardware and software hacking and modification among communities of players. Speculative practices in design and art thus offer platform studies a crucial mode of extending its method to include the experimentality of scholar-artists as well as historians" [12, p. 364].

Each meta artefact delivered as part of the practice side of this thesis results from an inside-out approach of actively engaging with the subject medium in order to understand its affordances and constraints in a creative context. As a result the practice side of this thesis tacitly and self-reflexively explores, both through the development processes and final interactive works, arcade interface aesthetics, art, and materiality.

### 2.3 ART-BASED RESEARCH

This hybrid method draws in particular from the art-based research approaches of McNiff [123], Gray and Malins [69], and Scrivener [134, p. 69-80], all of whom emphasise reflective practice and academic rigor. Dunne's studio centered critical design approach [155] is also a strong influence.

Art-based research is defined by McNiff as 'the actual making of artistic expression in all of the different forms of the arts, as a primary way of understanding and examining experience' [123, p. 29]. Gray and Malins characterise 'artistic' methodologies as using "a pluralist approach and the use of a multi-method technique, tailored to the individual project" [68, p. 72]. Indeed McNiff considers the drawing up of a bespoke methodology to suit an art-based enquiry as an art in itself [123, p. 34].

Scrivener describes the implementation of creative practice as part of a doctoral thesis as not so much a problem solving issue, but "a response to a set of on-going issues, concerns and interests expressed through one or more artefacts" [154, p. vii].

The practice aspect of the study is phenomenological, that is, based on the first person experiential point of view. It relies on the artist

verbalising and putting into words the tacit knowledge of the creative process.

"There is no better way to understand a particular aspect of creative practice than to research it in this direct way" [97, p. 31].

All too often this reactive and adaptive process is taken for granted by creative practitioners and seen as unimportant, when in fact it is of valuable use to anyone who wishes to replicate the processes outlined. This process is "qualitative, naturalistic, and reflective" [97, p. 72].

The practice-based artefacts from this study are art games (*Control* and *Arcade Operator*), in other words games designed with the intent and purpose of being critical artefacts, and game art (*VR SuperGun*), art that uses an existing arcade videogame platform as its source canvas.

#### 2.4 GAMES AS ART

The collision of art and games falls under several specific labels, as defined in *Gamescenes* [21, pp. 7-8] by Bittanti and Quaranta. A brief glossary of terms describing different permutations of videogames and art is as follows:

- Artgame: Independent or commercial "may employ novel interfaces, non-mainstream narratives, retro visual language, experimental gameplay and other strategies".
- game art (lower case): artwork that happens to be in a game.
- Game Art (capital letters): an artwork based on videogames, or using a videogame platform or technologies as a medium.
- Art games: games made intentionally for art purposes to "explore the game format as a new mode for structuring narrative, cultural critique".

However, a game artist is a game artist. One who "operates simultaneously in visual arts and plastic arts and synthesizes skills and expertise traditionally close but separated" [58, p. 204], one who "plays with (or against) games" [146, p. 14].

It's also possible for a videogame to be art or not in itself without cleanly falling into the categories of art-game, game-art or similar, as put forward by Stuckey [88, p. 51] "as a new art form, videogames need to be understood and appreciated as distinctive, with distinguishing structures and unique strengths". In *Neoludica*, Ferrari states that "video games are art, and they have recently acquired a crucial



influence on other art" [58, p. 11]. Game Art (and Art games) exist as a category of media art, as such the artefacts from this study have been targeted at both game and media art centred publication outlets.

The earliest documented example of an arcade videogame presented in the art gallery domain known is *Mike Builds a Shelter*, by Michael Smith, Dov Jacobson, and Alan Herman. The Cold War themed coin-op has the player gather bricks to build a nuclear fallout shelter before the game is invariably ended by an onscreen explosion [115]. It was originally exhibited at Leo Castelli Gallery in New York in 1983 [157], and is referred to by the New York Times as "the first videogame as fine art" [86].

By using the very materiality of the arcade interface as a self-reflexive medium these artefacts aim to meet the criteria set for art by Bogost "to issue a specific challenge to a medium from within it . . . that if nothing else is most certainly a feature of art" [22, p. 17].

## 2.5 A GAME STUDIES AND MEDIA ART HYBRID

While this thesis reaches across several disciplines, its scope can be categorised mainly under the overarching areas of game studies and media art, with multiple interconnecting strands linking both while simultaneously borrowing from related cognate fields. Game studies is in itself inherently interdisciplinary, incorporating a wealth of scholarly approaches. In the inaugural issue of game studies journal, Aarseth (2001) writes:

"Computer games are perhaps the richest cultural genre we have yet seen, and this challenges our search for a suitable methodological approach. We all enter this field from somewhere else, from anthropology, sociology, narratology, semiotics, film studies, etc, and the political and ideological baggage we bring from our old field inevitably determines and motivates our approaches. And even more importantly, do we stay or do we go back?" [4].

My own previous background in graphic design, interaction design, and game design at the beginning of this study certainly influenced its starting point and initial trajectory. However it was important on a personal development level as a researcher and artist to branch out into new territories of scholarship and practice.

The methodology has developed organically in response to the research aims, and also due to peer feedback from the media art and

game studies communities to publications made over the thesis journey, providing vital feedback and impetus.

## 2.6 IMPLEMENTATION

The implementation of this thesis study follows a parallel process where the written and material thesis elements occur simultaneously, reacting to each other as the process of discovery continues. This reflexivity is a characteristic of the rigour described by Scrivener [154] that forms an essential part of artist and designer driven research work.

In the initial stages of my process I had envisioned going down the path of having each practice-based exploration centred around a bespoke physical interface, either standalone, or controlling a modified pre-existing software piece, with minimal programming involved. However over time building with code took precedence, with the use of pre-existing arcade hardware as a creative material concentrated on artefact three. This change of material emphasis from hardware to software was made in order to greater understand from a first hand perspective the processes and challenges involved in designing and programming game worlds within the equivalent of legacy arcade system constraints. Software only artefacts also allow for ease of duplication and distribution, which proved advantageous when applying for exhibition opportunities.

The reflective practice portion of this study is concentrated mainly on the challenges of translating the thematic points of the main thesis into the interactive artefacts. Data and feedback was gathered from a wide range of sources, including:

- Historic and technical research into arcade development industry and development processes, using archive material and first person interviews.
- Materials based explorations and creative process (experimentation with toolsets. Including game design, hardware interface design, chiptune music composition, pixel art and animation, tile based level design, coding).
- Field trips to arcades, game museums, and videogame exhibitions.
- Documentation of artefact development through screenshots, screencasts, audio and video recordings, notes, and sketches.
- Peer feedback including:
  - Academic publication peer review.
  - Indie game jury results.

- Online game reviews (both text and video based).
- Reaction to artefacts in live exhibition space.

During the journey of this thesis insights have been gathered from arcade game developers, new media artists, and practitioners working in game art and art games. This wider sampling of qualitative data has contributed to the primary research aspect of this dissertation, allowing for increased triangulation of the findings. All videogames cited are listed in the Ludography section, and referenced by publisher and year. All remaining sources are indexed in the main bibliography section and referenced numerically.

## 2.7 ARCADE MATERIAL AS TOOLSET

The improvisation of pre-existing arcade hardware and control systems into game creation tools by the arcade industry in the 1980s and 1990s sets a precedent for the reconfiguration of arcade platforms into expressive digital canvasses, paralleling the creative reappropriation of closed gaming platforms into creative digital mediums by the emulation, hacker, and media art communities ([Chapter 3](#)).

JAMMA era arcade conversions were not designed through a singular development toolset or production methodology. Development teams used a combination of off-the-shelf packages such as the pixel art package Deluxe Paint alongside their own custom methods for transferring graphics from the screen to the target medium. As discussed in [Chapter 5](#), Arc Developments fitted a custom pause button to their *Forgotten Worlds* game board to facilitate their artists as they manually reproduced the graphics, while Special FX developed their *Midnight Resistance* conversions by directly filming the monitor with a camcorder to produce pausable VHS recordings for artist reference.

Similarly the teams who produced the original arcade titles for the coin-op market produced their work largely through a mixture of off-the-shelf and in-house developed game creation tools and techniques. Games were often developed in parallel with the design of their computational platforms, or on company exclusive game boards.

Sega's Digitizer System was a light pen controlled custom hardware workstation for graphics production. Its display was split across two CRT monitors, with one display used for the zoomed out view and the other showing the given graphic in close up detail. Images from the system were exported to ROM chip, the slow speed of this method leading to fewer save points by the artists [[166](#), pp. 175-176]. A later version shown in 1992 documentary 'The Fantasy Factory' re-

tains the dual screen system but used a mouse based control scheme [118].

The merging of the game play and game designer interface is evident in the joystick controlled TAECOM-11 graphics workstation used by Taito in the mid 1980s. The proprietary system was built from modified *QIX* (1981) arcade cabinet hardware, and used recycled monitors from table arcade cabinets. Taito continued to use their 20 button arcade joystick as an art creation interface when moving to Sharp X68000 based development systems in the 1990s [176].



(a) Sega Digitizer used to create artwork for *Fantasy Zone* (1985).



(b) Taito TAECOM-11 joystick interface (circa 1985).

Figure 1: A Sega Digitizer using light pen input (left) and Taito's 20 button joystick (right) used with the TAECOM-11 graphics workstation. Image source: <https://vgdensetsu.tumblr.com/post/179656817318/designing-2d-graphics-in-the-japanese-industry>

### 2.7.1 Era-Equivalent Audiovisual Constraints

The aesthetic and practice conditions set for the creation of each artefact are inspired by the resolution, colour palette, sonic, and input device constraints of JAMMA era game platforms (Chapter 4), while making necessary compromises to best harness modern system requirements. For example, both *Arcade Operator* and *Control* use a restricted colour scheme formed from an amalgam of the 4 colour modes of the IBM PC compatible CGA colour palette. However, both use a 16:9 aspect ratio instead of the typical retro 4:3 screen dimensions. This is in part shaped by the medium used, Stencyl is designed for both mobile and desktop game development, and offers a baseline 480 x 320 pixel resolution optimised for mobile touchscreens.

The memory restrictions of Stencyl's tile based system require optimisation befitting the target aesthetic, but also allow 4x scaling to 1920 x 1280. Stencyl's 16:9 resolution also fits modern desktop display defaults, when combined the keyboard as a baseline interaction

method, it ensures that both games require no custom settings to run, maximising their accessibility and opportunities for public dissemination.

VR *SuperGun*'s 3D graphics were designed using a combination of late 1990s low polygon modeller Milkshape 3D and contemporary voxel editor MagicaVoxel. The former was selected due to its era specific toolset and aesthetic, with the latter chosen for its blocky vector visuals and relatively expedient working process. WebVR delivers browser based, platform agnostic virtual environments, accessible through standard 2D displays or virtual reality headsets, and is ideally suited to reproducing the hard polygon aesthetic of early 1990s 3D arcade games.

Both experimental meta games also use music and audio effects produced in *Little Sound Dj* (see [Chapter 3](#), [Chapter 6](#), and [Chapter 7](#)), ensuring an authentic chiptune sound produced through gaming hardware.

### 2.7.2 Production Constraints

As far as possible all aspects for each artefact were produced from scratch. Each artefact required developing a bespoke coding solution, entailing a steep learning curve. The following constraints were set for the production of each artefact:

- All artefacts should be original and make new contributions to their respective fields.
- To use production techniques that as closely as possible approximate 1980s and 1990s low resolution pixel art, low polygon, and chip audio aesthetics. For example, avoid the use of modern graphics filters and effects.
- All graphics, sounds, and animations should be produced independently.
- Use the basic arcade control scheme of 8 directions of movement and digital button inputs for both art games.
- To learn the necessary programming skills needed to implement each artefact to suitably understand first hand the technical hurdles of working within legacy equivalent computational constraints.
- Usage of baseline PC specifications with no graphics acceleration requirements, to focus resources, allowing greater accessibility by outside audiences, and ease replication and distribution logistics.

## 2.8 THE EXPERIENTIAL COMPOSITE

At the outset of this thesis the methodology was defined with regard to both the practice-based element and the historic, technical, and aesthetic theory research aspects implemented. The reflective practice aspect of this research is focused through the design, development and implementation of three critical meta artefacts, the themes of which are interweaved with the theoretical, technical, and historical research elements of the dissertation.

All three experimental game-based artefacts of this thesis combine to form a self-reflexive, experiential composite overview of the arcade interface. The motif of the arcade videogame cabinet is used to visually represent the main thematic areas of each artefact ([Figure 2](#)), although a certain amount of overlap does exist between each.



Figure 2: The Arcade Interface Meta Trilogy as mapped to the physical aspects of the arcade videogame interface.

- *Control* is a meta game about interface constraints, it is mapped to the control panel and visual display.
- *Arcade Operator* is an art game experiment in articulating the operator level arcade interface. It is visually linked to the coin-op internals.
- *VR SuperGun* expands the materiality of the arcade machine into networked virtual space, and is signified by the exterior shell of the coin-op cabinet.

The following three chapters reflectively document the design, development, and implementation of each self-reflexive meta artefact. *Control* ([Chapter 6](#)) and *Arcade Operator* ([Chapter 7](#)) are both art games, each built from the ground up to articulate their conceptual themes.

*VR SuperGun* ([Chapter 8](#)) is game art, augmenting the JAMMA hardware standard to explore its own material and aesthetic properties.

Each artefact uses the arcade interface to experientially articulate issues surrounding arcade videogame aesthetics and materiality. The background research and practice-based process of each experimental prototype combine historic, technical, and design research with first hand tacit engagement with the material of the arcade videogame interface in hardware and software form as interactive aesthetic medium.

## 2.9 EVALUATION STRATEGY

My methodology uses peer-review as an essential form of critical assessment. This is used complimentary to the evaluation of data collected from the sources previously outlined, alongside knowledge gained through the tacit and reflective nature of the production process. The inclusion of peer-review follows the naturalistic inquiry criteria of Lincoln and Guba (1985) adapted by Brunnel for ceramic design in 1998 [68, p. 73]. Naturalistic research is a strategy suggested for 'real world' research settings.

To date outputs from this thesis have been published through academic journals, exhibitions, conference proceedings, invited talks, and also through online distribution of the *Control* and *Arcade Operator* artefacts, as well as online trials of the *VR SuperGun* (see [Appendix A](#)). Feedback was received from anonymous peer review, and through the online gaming press and exhibition coverage. Additionally valuable feedback has been received in person at talks and exhibitions. Through publishing I have built a network with other researchers and artists working in related fields and have gained valuable advice and feedback that has translated directly back into this study.

This strategy of publishing across the spheres of indie games, art institutions, and through traditional academic avenues was employed to keep my work accessible to the audiences culturally linked with the subject matter. Concurrently this consistent engagement contributed to ensuring reflectiveness alongside academic and creative rigour throughout the thesis process.





## Part II

### ARCADE INTERFACE ANATOMY



## ARCADE VIDEOGAME INTERFACE AESTHETICS

---

This chapter provides an introduction to the aesthetic and connective properties of videogame interfaces. It considers the arcade videogame interface as a holistic communicative and creative link that includes but also extends beyond play orientated input and feedback mechanisms. With the correct emulation and homebrew tools, videogame platforms that were originally designed as consumer only devices become malleable forms that can be interfaced at artist and developer levels, allowing previously closed hardware and software systems to function as reconfigurable digital materials.

### 3.1 AN ARCADE INTERFACE TAXONOMY

This thesis puts forward four categories of interfacing with and within arcade platforms, these are User Context, Machine Level, Game World, and Environmental:

#### USER CONTEXT:

- Player (consumer level).
- Operator (maintenance and technician level).
- Developer (arcade development team, hardware and software).
- Artist (creatively recontextualises play-only arcade platforms).

#### MACHINE LEVEL:

- Input:
  - Directional controls, i.e. joysticks, steering wheels, and other bespoke controllers.
  - Input buttons.
  - Coin slot.
  - Game settings DIP switches.
  - PCB test functions.
- Feedback:
  - Video.
  - Audio.

- Tactile Feedback (non-standard feature).
  - \* Passive Tactile Feedback, i.e. button press resistance.
  - \* Active Tactile Feedback, i.e. vibrations triggered in-game.
- Machine-to-Machine Interface:
  - Game PCB to arcade wiring harness, i.e. JAMMA standard connection.
  - All communicative links of the game hardware.
  - Arcade network functionality.

#### GAME WORLD:

- Diegetic Interface (feedback delivered inside the game world).
- Non-Diegetic (static interface, i.e. high score, energy bar).

#### ENVIRONMENTAL:

- Hardware presence (physical and ergonomic impact of the hardware platform on player experience including peripheral vision, controller grip, and gait while playing).
- Arcade environment (public or domestic, ambient noise, presence of spectators).

##### 3.1.1 *Input and Feedback Mechanisms*

Chris Crawford defines interaction as "an iterative process of listening, thinking, and speaking between two or more actors" [77, p. xx], emphasising clear communication as critical. The player must understand the machine, and vice versa.

For example, after a player inserts their coin into a videogame at an amusement arcade, they are presented with a text prompt through the machines visual interface to select either single player or two-player mode. To articulate back their choice of single player mode, the player selects the button labeled '1'. An audible chime from the speakers and a change in the visual interface that affirm the chosen option are then relayed back to the human as audio and visual feedback by the computer. Without this feedback, there is a disjoint in the communication, and as a result the interface is rendered defective.

A videogame's communicative anatomy comprises of two elements, input and feedback. The input side is most commonly associated with

the controller-centric perspective of game interfaces. This view encompasses manual controllers such as the keyboard or joystick, alongside touch-based gestural interfaces, in addition to freeform gestural interfaces, for example, Nintendo's Wii Controller and the Oculus Rift Touch Controllers. Play-only platforms such as arcade machines and game consoles deliver a consumer level interface experience. However, the game developer interacts with the host technology at a more raw and visceral level, where the inner workings of the computing system are exposed and directly addressed through code.

Feedback forms the second component of the transmission loop. This feedback is most commonly delivered through visual, auditory, or tactile means. The harnessing of the olfactory senses as feedback targets for digitally originated feedback in videogaming has yet to reach consumer level. In game design the vibrating 'rumble' feature of game controllers is common method used to enhance immersion by adding the extra tactile dimension of haptic feedback. For example, The Playstation 2 version of Sony's *Rez* (2001) uses a dedicated tactile feedback called the trance vibrator unit to provide feedback accompanying its psychedelic visuals. In the arcade domain, the sit-down editions of Sega's *OutRun* (1986) features force feedback delivered through the steering as feedback for in-game collisions [156].

Visual feedback is delivered mainly through the screen, but also can refer to other visual augmentations to a videogaming system, such as the flashing lights on the *A.P.B.* arcade cabinet (Atari, 1987). In *APB* the player drives a police car and must arrest a set quota of criminals and traffic law violators on each level. The player must also collect doughnuts to increase their high score. Whenever the player is in pursuit of a perpetrator's vehicle, the siren lights on the cabinet activate, adding to the games immersion.

### 3.1.2 *Static and Dynamic Interfaces*

Galloway cites Vilem who described the screen as "a two dimension plane with meaning embedded in it or delivered through it" [64, p. 30]. This meaning can be textual, image-based, both abstract and figurative. Galloway also uses the term of the intraface to describe the ether that holds together the various layers of the visual interface, the interplay of diegetic (dynamic) and non-diegetic (static) interface elements.

Non-diegetic game interface elements are those that cannot be interacted with directly, that exist to solely provide visual feedback [136, p. 80]. For example, in the game *Asteroids* (1979), the static interface

elements are the current score and the number of lives remaining. Dynamic or diegetic interface elements are feedback elements that are incorporated into the game environment itself. In the *Grand Theft Auto* series, damage that is visually manifested on the player's vehicle provides dynamic feedback to the user on how effective a driver they are, rather than relying on a numeric value.

The arcade game *Ghosts 'N Goblins* aka */Makaimura* (1985, Capcom) delivers diegetic feedback through the costume of the main character, Arthur the knight. The player character can survive one direct hit, with the damage incurred communicated to the player through Arthur losing his armour. By displaying feedback through the game world rather than the static interface, the player is able to stay focussed on the gameplay action.

### 3.1.3 *Interface Convergence*

The division between screen-based visual interfaces and the manual interface of the hardware controller has become less distinct since touchscreen technology became a viable part of modern consumer electronics. The screen has become a new form of tangible surface, despite its limited tangible feedback capabilities. The ability to reach deep into the screen physically in commercial video games, in a reverse of *Videodrome's* signature hallucinogenic sequence (1983), can only be done through virtual rather than physical augmentation of the visual display. The glass barrier ensures that games presently remain solid to physical touch, rendering the play field only malleable through extension into the digital space visually through a digital embodiment, or sonically via three-dimensional sound.

### 3.1.4 *Interface Accessibility and Gameplay Challenge*

While remaining intuitive and clear, a game interface must engender a sense of challenge. This level of difficulty is dependent on the audience as well as the host platform. A gamer indulging in a five-minute play session on their smartphone requires simple, intuitive controls. On the opposite end of the spectrum are those who thrive from the intrinsic challenge of mastering a complex experience, taking satisfaction in mastering a task that requires more rote learning than intuition.

Take for example the text mode visual overload of *Dwarf Fortress*, where the player must invest months to master the game control system, memorising a myriad of keyboard shortcuts while navigat-

ing and understanding a multitude of statistic packed status screens. However, the level of interface complexity in the *Dwarf Fortress* computer game is at odds with the accessible nature of arcade interfaces. Arcade games are consumer level interfaces, where the gameplay must be easy enough to ensure a continued stream of customers in public space, yet difficult enough maintain a healthy profit for the arcade operator.

### 3.1.5 *Game Aesthetics and the Experiential*

In *Interface Criticism: Aesthetics Beyond The Buttons* [10] Cramer identifies two views of aesthetics when applied to the interface, one been the philosophy of art, the other a more generalistic term to mean the ‘look and feel’. Additionally Anderson puts forward the view that

“computer games are aesthetic interfaces per se. Opposed to the functional dimension of a pragmatic software interface (as in the editing of text or images for example), a game interface highlights an experiential dimension of the interface” [10, p. 178].

Linking to the experiential as part of the aesthetic experience, Kirkpatrick cites Kant (1795)

“what Kant means by play in this context refers primarily to imagination and its relationship to cognition, For him, the play of these faculties with each other, stimulated by particular kinds of experience, is the basis of our experience of the beautiful” [95, p. 22].

The process-based artworks of the Fluxus movement along with the situationist art of Marcel Duchamp are referenced in *Understanding Machinima* as the roots of playfulness in art [132, p. 131]. The surrealist artist Duchamp’s exhibiting of a urinal in 1927 was a play not only with the conventions of artistic sensibilities, but also with the market and establishment [95, p. 34]. Duchamp’s work is also categorised by Catlow in *Artists Re: Thinking Games* as situationist, that is, “overturning the established order” [35, p. 10].

## 3.2 BUILDING AN INTERFACE FOR PLAY

One of the earliest documented participatory videogames, and interfacing of the general public with computers as a mode of leisure took place in 1958 at Brookhaven National Laboratory, a nuclear research facility in Suffolk County, Long Island. William Higinbotham, a nuclear physicist who had worked on the Manhattan project, and

afterwards became a campaigner for nuclear non-proliferation, led the team that built *Tennis for Two*, an interactive exhibit intended for public engagement.

“I knew from past visitor’s days that people were not much interested in static exhibits, so for that year I came up with an idea for a hands-on display, a video tennis game” [30, p. 28].

Housed at the display for BNL’s Instrumentation Division, *Tennis for Two* used a circular 5 inch diameter oscilloscope screen as a visual display. Auditory feedback was provided through a basic sound effect that is heard when the ball is batted. The use of an oscilloscope as *Tennis for Two*’s graphical display unit enforced a monochromatic, stripped down line drawn aesthetic, that can be seen taken in a more intricate form to the z-axis in *Battlezone* (1980), and the colour vector graphics of Atari’s *Star Wars* (1983).

Brookhaven National Laboratory’s mainframe computers were imposing machines that filled entire rooms. From the general public’s point of view, the fact that these new and largely technologies were housed at a nuclear research facility during the cold war added to their ominous nature. The computer used for *Tennis for Two* was a Donner Model 30 vacuum tube analog computer [99], with the game program assembled as a physical circuit of logic components [15]. It was a machine built by computer scientists for computer scientists.

By building *Tennis for Two*, Higinbotham harnessed play as an introduction to human-computer interaction for the general public, easing any misgivings felt by people interacting with computer technology for the first time. The success of Higinbotham’s invention was made evident by the long lines of people who waited in line to play the game during the 1958 BNL visitor’s day [30, p. 23].

### 3.2.1 Videogame Interface Emergence

*Tennis for Two* is important in the early lineage of video gaming as it set out the basic template for a two-player arcade game interface. The game’s two manual controllers were built using industrial potentiometer knobs for onscreen paddle movement alongside a serve button, each of which was encased in stainless steel boxes connected via cables to the computer. Alongside the laboratory oscilloscope and the bulk of the analog computer, the physical visage of the machine is very much representative of the cold war military industrial complex that it was born from. Its gameplay mechanic and dual controller physical interface, alongside the audio and visual feedback elements



were later echoed by Ralph H. Baer's *TV Game System* (1966). However, both inventions were isolated in their development, with Baer having never heard of Higinbotham until 1985 [19], when Nintendo cited *Tennis for Two* as the original tennis videogame in response to been sued by Magnavox over trademark infringement [19].

Higinbotham was called as a witness by Nintendo, who argued that *Tennis for Two* was the original tennis video game, thus negating Magnavox's copyright claim. The judge ruled that since the oscilloscope display was not receiving a standard video signal, it therefore could not be considered a 'videogame'. At the time, a mixture of naivety and legal obfuscation was enough to ensure this minor technicality exempted *Tennis for Two* from falling under the definition of videogame.

### 3.2.2 Interface Functionality vs Playability

Atari's *Pong* (1971) took the TV tennis concept and translated it to the amusement arcades, it also (predictably) resulted in Atari being sued for copyright infringement by Magnavox [94, p. 15]. It was also the second commercially sold coin-operated arcade videogame. The first of which was *Computer Space* (1971), which was also produced by Nolan Bushnell before starting Atari. Similar to *Pong* it was a close copy of an existing game, a lab experiment called *Spacewar!* that originated in 1962 at Massachusetts Institute of Technology as a tech demo and experiment for the DEC PDP-1 computer. The extravagant molded fibreglass body of the cabinet reinforced the science fiction scenario of the game, even making an appearance in the film *Soylent Green* (1973) as a futuristic home fixture.

Despite high production values, *Computer Space* failed to translate to the public space. Its control console and onscreen display elements did not communicate their function clearly to the user, and the game demanded more time to learn than a single play would allow. *Computer Space* had an interface that performed all of its functions correctly from an engineer's point of view, there was a button for each action required of the player. Unfortunately, the unintuitive visual mapping of the buttons and the lack of a pre-existing visual language for videogames that the layperson could connect with, led to *Computer Space* failing commercially.

By contrast, the zen like simplicity of the *Pong* interface ensured its success. *Pong's* arcade cabinet design is minimal with clean typography, the wooden veneer body and stainless steel control panel striking a balance between the industrial and 1970s home decor. A sin-

gle line of instructions that reads 'Avoid missing ball for high score' was placed on the front of each cabinet between the two rotating potentiometer controllers. The mapping of the physical controllers to their respective onscreen paddles is made obvious to the player, while turning each knob clockwise or anti-clockwise generated an immediate and appropriate response, changing the vertical position of the player's onscreen paddle. Simple audible tones accompany the sound of hitting the ball, and also missing the ball. The ball itself isn't round, but square, the beginnings of the pixel aesthetic.

### 3.2.3 *Utilitarian Interface Layers*

Looking inside of a *Pong* cabinet we see the interface construction laid bare. The circuit board hangs attached to the side of the cabinet, with wires reaching outwards to the television monitor, controls, power supply, and coin mechanism. It is unembellished and utilitarian, a nod back towards the industrial feel of BNL's *Tennis for Two*. The outward face of the game presents a polished visage in comparison to the exposed raw components that power it.

In effect the cabinet front is a boundary both physically and visually, separating the player from the electromechanical and computational processes that power the interactive game experience. This view behind the curtain is denied to the general public, with only the game technicians and the arcade owner making contact with the core mechanics of the system. While the developer uses machine code writes directly to the metal, here the coin-op owner or technician physically views and interacts with the machine circuitry.

## 3.3 THE EMULATOR AS INTERFACE

The original *Pong* arcade machines are now in museums and private collections. If a visitor to the Computerspeilmuseum in Berlin wants to play *Pong* they need to arrive at a set time where they will be allowed to play the delicate artefact with supervisor assistance. For someone who doesn't have access to the original *Pong* hardware, the next best option for experiencing the original game is through an emulator. An emulator is a piece of software or hardware that recreates a computer system through a different computing platform.

Most classic videogame consoles and home computers exist in emulated form, which are usually created by enthusiasts without any official backing from the original machine creators. Legal difficulties do exist, and to circumvent these issues most emulators are distributed

without core proprietary code, for example system BIOS files. Users are typically asked to sign a disclaimer stating that they are going to fill the gap by legally extracting the code from the ROM chips or system disks of their own working machine. Yet in practice most users will simply conduct a web search to find the missing files for free through a less than legal source.

*Pong* is one of the few anomalies in videogame emulation since it wasn't actually programmed but 'built' electronically as an analogue circuit. In regular emulation, the original program code is 'dumped' as a ROM file taken direct from the original game circuitry in the case of a cartridge or arcade PCB system, or extracted from the original tape or disc. This program ROM is then loaded into an emulator for the chosen classic system, just as an original disk or cartridge is loaded into the original hardware. Recreating an analogue videogame through code is directly comparable to the creation of virtual analogue synthesizers, where the circuit and the voltage flow through its components are modelled through code. DICE<sup>2</sup> is one such program that simulates the original *Pong* arcade logic circuits on a home computer [24].

<sup>2</sup> DICE, a Discreet Integrated Circuit Emulator.

### 3.4 BIT ROT, SCANLINES, AND GLITCH ART

It is necessary to archive and preserve digital culture that has not already been committed to the online space. Physical machines and data storage mediums are not impervious to time and wear. Bit rot, the phenomena of magnetic storage mediums losing vital sectors of their information due to degradation of their physical makeup, proves that the digital world is not impervious to the environmental forces of the analogue world. However, recreating a classic arcade game on a modern computer works to the extent that an eBook can recreate a print book. Using an original tangible controller with an emulator through a custom adaptor, for example connecting MAME to a Sanwa brand arcade joystick and buttons mounted in a custom USB control panel instead of a PC keyboard, can closer approximate the original experience of playing the arcade game as it was originally experience.

The kindle eBook reader provides an immaculate paper white screen, and the ability to store many books in a compact physical form. Subjectively this can be interpreted as convenience at the expense of character. A paper-based book takes up more room, it can be easily torn and the paper fades and changing colour over time. Whether or not these weaknesses of paper books are seen as a hindrance or welcome quirk, they remain a part of the experience of interacting with

that medium. Similarly, when a game intended for original viewing through a cathode ray tube-based screen is viewed on the immaculate high resolution of a modern computing system, convenience is added, but also part of the original medium's essence is lost.

Admittedly, CRT screens are inconvenient on several levels. Compared to flatscreen monitors, they are bulky in size and weight, and their low resolution makes it difficult to focus on smaller details onscreen. Additionally, the scanline interlace flickering of tube base video screens can induce eyestrain. Also when using an analog signal, if a lower quality video connection cable is used that doesn't separate the red, green, and blue component video signals, the image becomes less defined.

Game designers have positively and creatively harnessed these imposed constraints and colourations. An example of this in effect is shown in the transparent waterfall graphics in *Sonic The Hedgehog* on the Sega Mega Drive console, made possible by blurring two shades of light grey into a semi-opaque effect. When viewed through an emulator without CRT simulation the effect is lost [153].

In a 2013 interview with John Szczepaniak, game artist Aziz Hinoshita of Japanese game developer Athena describes how they used a CRT television as a second display on their development PC in order to effectively design their graphics for cathode ray tube displays:

"You also had a video out, so you could check out any stills or animations on a television monitor, connected to the PC. So you could check if the colours were right, or how the animations worked. Creating those kinds of effects. Like CRT bleeding and stuff . . . It just looks different" [167, p. 146].

### 3.5 EMULATION, ROM HACKS, AND PLATFORM ENHANCEMENTS

Aside from recreating the features of a vintage computing platform, many emulators add extra functionality that serve to expand the recreated platform beyond its original uses, making direct to metal processes open to the consumer that in turn enable them as creators. *NESicle version x.xx* (1998) by Bloodlust Software emulates the Nintendo NES system [6]. When a .NES ROM file is loaded into the emulator it can be viewed in tile mode. Tile mode displays the component graphical elements of the loaded game ROM, alongside the HEX values for their assigned memory locations and other binary variables such as their colour palette. If the ROM file for *Super Mario Bros.* is loaded and the tile view is enabled, it is possible to locate the graphic tiles that are used to compose the sprite for the game's main charac-

ter, Mario, and redraw his appearance using the emulator's built in image editing tools. The edited ROM file, known as a ROM hack, can then be saved and ran as a normal game. It is also possible to take a hacked ROM image and transfer it to a physical ROM chip, allowing the modified code to run on the original system hardware.

Through NESTicle and other ROM hacking tools, it is possible to edit and experiment with the visual interfaces and control systems of classic video games. Some ROM hacks are purely functional and address existing issues in the game, for example, making a Japanese language only game accessible to a wider audience by replacing the original dialog with English language substitutions. Other ROM hacks go down a more conceptual route; *Super Mario Clouds* [13] by Cory Archangel is a seminal example of the ROM hack as media art. *Super Mario Clouds* is a ROM hack of the game *Super Mario Bros.* (1985), reducing the game down to a minimal level, where all visual interface elements are rendered invisible, apart from the sky and clouds.

Within the video jockey sphere, The VJ works of Entter (2002-present) incorporate sprites ripped from arcade ROMs complimented by original pixel graphics sharing the same 1990s 16-bit arcade visual style, manipulated at live performances in sync to chiptune music through custom built display and control software. The animated scenes also incorporate imagery from contemporary pop culture drawn within the style of '80s and '90s arcade graphics. On his chosen visual style Ligre comments "I work with pixel art because it's a sort of self-imposed limitation. It makes you express a lot with less" [55].

The early home computer systems such as the Commodore 64 presented the command line of the BASIC programming language as their initial start up interface, encouraging users to creatively code for their machines, however the game consoles were intended solely as playback devices. Emulators recreate this core software interface, but also expand on it.

In the cases of Nintendo and Sega, only licensed developers were officially permitted to develop software for their systems. Another factor that made creating for these platforms so exclusive was that specialist development systems were required for the task, which were not on sale to the general public. In addition, the game cartridges for console systems were manufactured strictly under license from Nintendo or Sega, although bootleg cartridges and pirate 'backup' copy devices existed on the grey market.

As with the emulator scene, modern development systems for classic videogame hardware are made by enthusiasts with detailed and

often self-taught knowledge of the software and hardware architecture of the original platforms. These software interfaces provide access to previously inaccessible aspects of the console platform, and ease the development process for the classic computer systems. For example, MAME presents a series of advanced debug options that allow a programmer to examine and modify a game as it is running [150]. MAME also features a mode to view tilemaps and colour palettes, allowing the user select, zoom, and rotate the component graphics of the game ROM [169].

Complimentary to software emulation and homebrew development kits, vintage gaming hardware is augmented into the modern age through the addition of third party peripherals. These devices add functionality such as USB file storage, network connectivity, and high definition enhanced audio and visual output. In these instances, the interface effects of platform constraints are embraced, but creatively expanded beyond when necessary to unlock further creative functionality. The HD output options contradict the aesthetic ideal of the CRT software filter, showing that the phosphor blur is a nostalgic as much as aesthetic preference.

### 3.5.1 *Videogame Music Interfaces*

In 1989, Nintendo released the Game Boy portable gaming console. Designed by Gunpei Yokoi, it was an evolutionary step beyond Nintendo's Game and Watch series of LCD-based portable games, a videogame equivalent of the Sony Walkman, allowing access to a library of interactive games on the go. The system's most basic revision, the Model DMG Game Boy (Dot Matrix) is equipped with four sound channels (two pulse waves, a 4-bit wave channel capable of playing samples, and a noise channel) [39, p. 76].

Apart from the nostalgic view, there are several reasons why the Game Boy, and low fidelity chiptune music in general have been embraced by modern musicians. One is the appeal of working within constraints rather than navigating a bewildering interface of feature bloats in modern music software. Another factor is that the Game Boy provides an affordable alternative to pricey electronic music equipment. Finally, the sound from Nintendo Game Boy has a raw, unfiltered edge. This primitive level of sound synthesis is immediately associated with vintage videogames, and has been adopted into the high-end systems that it rebels against.

Visually the Game Boy can display four colours onscreen simultaneously, and is controlled through a simple four way directional pad

alongside four action buttons. While the visual display was improved in clarity over a series of system revisions up to the Game Boy Color (1998), the basic control and audio system remained the same. For over twenty years, the system has endured as a pop culture motif to the point that custom cases are available for high-end smart phones that camouflage them into the likeness of the original Game Boy.

Inevitably the Game Boy has become a popular machine for homebrew software and hardware development, and has received wider embracement as a musical instrument. Although Nintendo has produced its own music creation programmes, for example the Trippy-H sequencer included with the Game Boy Camera, the platform's abilities as a music creation tool have been pushed largely due to the efforts of the homebrew development community. The two most prolific of these creative tools are *Little Sound Dj*, also known as *LSDj*, and *Nanoloop*.

*Little Sound Dj* and *Nanoloop* are not endorsed by Nintendo, although Nintendo seemingly tolerates their existence since no legal threats have been made against the application developers. In order to use *LSDj* or *Nanoloop* with an original Game Boy console, the user must first obtain a grey market 'backup' cartridge, and then transfer the downloaded ROM image from their computer to the cartridge. These cartridges have the advantage of allowing the user to save their compositions onto their computer for backup purposes, as well as allowing them to playback and interchange music sequences between Game Boy software emulations and the original hardware.

#### 3.5.1.1 *Nanoloop*

The first cartridge versions of *Nanoloop* were released by German art student Oliver Wittchow in 1999 [179]. *Nanoloop* transforms the Game Boy into a music composition and performance instrument, but instead presents the user with a minimal, abstract graphical interface. This visual interface is based upon a 4 x 4 grid of squares, the user interacts with these shapes using the directional pad and control buttons, tweaking the sound parameters of each of these steps in the loop. Changes made to a square's properties are reflected visually as well as sonically, and the overall interface feel is more exploratory than *LSDj*. A fine level of control detail is compromised through the graphical interface while improving accessibility.



### 3.5.1.2 *Little Sound Dj*

In 2001 Stockholm-based Johan Kotlinski released the first cartridge version of *Little Sound Dj*. As with any ROM image, the program can also be used on other portable gaming systems and computers through emulation software, although the creator cautions “Keep in mind that sound emulation can never be 100%, mostly because the low-grade hardware used in Game Boys adds some characteristic noise” [101]. Indeed, the original DMG model is the preferred device for live performance and recording of Game Boy chiptunes.

*Little Sound Dj* uses a tracker-based interface, maximising the level of granular control that the composer has of the Game Boy’s music architecture, while fitting comfortably within the visual confines of the platform’s 160 x 120 pixel resolution and 4 colour palette. This level of miniaturisation is made possible through the numeric shorthand of the hexadecimal number system, allowing all inputted values to fit within a two-character space [102, p. 5]. Navigation is accomplished through the system’s four way directional pad and four buttons, although custom peripherals allow further manual control options of the application’s sound parameters. The learning curve associated with *LSDj* is steep in comparison to its nearest rival *Nanoloop*, but perseverance in mastering the text heavy interface opens up a high level of granularity and control.

### 3.5.1.3 *Game Boy Modification*

Both *LSDj* and *Nanoloop* are further augmented through hardware hacks, modifications, and custom peripherals. These mods enhance and expand the Game Boy’s hardware interface by adding features such as professional level audio out jacks, backlit screens for improved visibility, and MIDI interfacing to enable the connection of music control devices. The LED hack is an aesthetically as well as functionality motivated mod. It provides useful visual feedback, flashing in synchronisation with the current BPM rate of the device, while enhancing the visual appearance of the Game Boy in when used for playing music live.

### 3.5.1.4 *Chiptune Roots*

In 2003 chiptune music received a boost of mainstream press recognition when Malcolm McLaren, the manager of Sex Pistols, who had been around at the inception of the Punk and Hip Hop subcultures, was interviewed about his involvement with New York’s burgeoning chiptune scene. McLaren waxed lyrical about this ‘new’ subculture in interviews with *Wired* [120], and *The Guardian* [42]. However his



attachment to this scene was soon questioned online through an open letter by GW3M, a member of the Micromusic forum:

“Whilst micromusic.net welcomes interest from the music industry we feel that Malcolm’s statements have been at least inaccurate, certainly without acknowledgement of the 25 years of chip music history, and possibly even using ideas and concepts taken from us” [185].

It is indeed important to note that chiptune music didn’t begin in the early twenty first century, nor is it confined to the Nintendo platform. Chiptune music has existed as an international phenomena as long as the hardware to create it has existed, just existing under different names. Martin Galway [39, p. 31-33] and Jonathan Dunn [92, p. 248-250] are both renowned for their work written for the Commodore 64 SID chip for UK based game development company Ocean Software in the 1980s. Both Galway and Dunne combined their musicianship with their programming skills, using custom code to bring their compositions to life.

The veteran game music composer Yuzo Koshiro, famous for works including the soundtrack to *Streets of Rage* (Sega, 1991), began game music composition inspired by the type-in code tutorials of the Japanese game programming magazine Mycom Basic [100]. Koshiro also created a music programming language called Mucom88, allowing coding of FM synthesis music for the NEC PC-8801 series of microcomputers<sup>3</sup>.

Also as discussed in Chapter 7, arcade music developers of the ’80s and ’90s commonly converted their notation to assembly language, only hearing their music back on the native hardware after the process of transferring their code to a ROM chip that was then connected into the prototype arcade PCB.

Music composition on vintage computing platforms has also been pushed on since the early days by game hackers who removed copy protection from commercial video games, then redistributed cracked versions incorporating their own signature theme tunes and ‘greetz’ to their hacking cohorts in the introduction. The level of technical proficiency needed to compose on a Commodore 64 in the mid-1980s was considerable:

“To have a clearer picture we have to add that those times there were no music composer programs yet. Their tracks were composed as an assembly language program, they mixed sounds “by hand” and coded all filters effects themselves. One can imagine the patience and experience it needed” [143, p. 90].

<sup>3</sup> Mucom88 was ported to Windows in 2018 as an open source project: <https://onitama.tv/mucom88/>.

The game hacking scene is closely linked to the demo scene. Demos are audiovisual presentations where teams of coders, artists, and musicians work together to produce the most technically and aesthetically impressive presentation possible within the constraints of their host vintage platform. For demos that use modern hardware, the restrictions are imposed, for example a 64 kilobyte memory limit [103].

The early computer game musicians, demo coders, and hack intro / hacktro creators all had programming knowledge at their disposal, either individually or as part of a team. This combined skillset of coding and musicianship goes a step beyond use of pre-made tools like LSDj and Nanoloop, and is a common link among chip musicians of the 1980s and 1990s.

### 3.6 INTERFACE AESTHETICS AND AUTHENTICITY

In 2012, Disney released the videogame culture inspired movie *Wreck-It Ralph*. The film centers around Ralph, an antagonist character in fictional classic era arcade game *Fix-It Felix Jr.* Ralph is a non-player controlled character, a feature of the game's dynamic interface. He travels outside of his normal environment across multiple videogame platforms and genres on a quest to find his true self. In an opening scene, the arcade cabinet for *Fix-It Felix Jr.* is shown in an amusement arcade, alongside actual historic cabinets such as *Pong*.

This manufactured association with videogame history is reinforced in the physical space by Disney's creation of a limited number of *Fix-It Felix Jr.* arcade coin-ops <sup>4</sup>. These cabinets provide an experience that simulates the early 1980s arcade videogame, including tactile arcade microswitch controls, an authentic CRT screen with imperfect blurry scanlines, limited audio resolution, and even the character building battle damage of a game presented as a 30 year old museum piece. Instead of an arcade PCB, the promotional *Fix-It Felix* coin-ops PCs that load the game from an encrypted hard drive. Despite this security measure, an early version of the game code was leaked online, forming the starting point for copycat coin-ops [76].

<sup>4</sup> Ascribed in-universe to Tobikomi, a fictional game company from the *Wreck-It Ralph* universe analogous with Nintendo.

Jim Bagley's *WCWreckItRalph90* [62] is a homebrew *Fix It Felix* implementation programmed for the Z80 processor based *Tecmo World Cup '90* hardware [75]. By running on original 1980s arcade hardware it offers an additional layer of arcade authenticity that the official Disney coin-op lacks. In addition to the hardware platform used, its assembly language driven software production process also fits the 1980s movie narrative.

The desire to bring the intangible to the real is further manifested in the homebrew bootleg variations of *Fix-It Felix Jr* released for PCs and retro consoles. Two homebrew variations of the game exist for Sega's Mega Drive / Genesis [47] [96]. An 8-bit Nintendo NES version also exists as a hack of Brøderbund's 1983 puzzle platformer *Lode Runner* [170]. An unofficial fan made prequel also exists as *Fix It Felix Sr* for the Atari VCS (2013) [43], demaking the original's early '80s full colour pixel aesthetic within the constraints Atari's TIA chip. As gameplay experiences the *Fix-It Felix* bootlegs are more level demos than fully developed games, their appeal firmly rooted in their rarity and experiences as collector's items.

The promotional *Fix-It Felix Jr.* cabinet by Disney is faux-retro, the embodiment of a game that never existed. By manifesting as an interactive artefact, the movie narrative is anchored concretely in our physical universe. From 8-bit pixel art to a worn arcade cabinet patina indicative of decades of use, it successfully employs the functionally superfluous, but aesthetically authentic material constraints of classic arcade videogame interface aesthetics to enhance the credibility of its claimed vintage.

### 3.7 CONCLUSIONS

Low fidelity game platform aesthetics invoke an atmosphere very much synonymous with their originating time period. The retro aesthetic applies not just to gameplay, audio, and graphics, but also the colourisation the inherent imperfections of analog visual displays and the external shape and form of platform hardware. Both emulated retro games and modern retro-inspired games frequently attempt to recreate these additional interface layers with the aim of creating an era-authentic atmosphere.

Emulators and homebrew software development kits, alongside modern hardware additions for classic videogame systems ensure the continued survival of vintage computer gaming platforms. Authenticity is a prized attribute in emulation, whether exemplified as the fuzzy RF visuals on a CRT-based television set approximated through simulated scanlines, or the unseen but consciously valued process of analog circuitry simulation in the *DICE Pong* recreation.

Although surpassed technologically, the retro game aesthetic has not been made redundant. As time passes the collective knowledge base in terms of how to best technically and creatively harness legacy gaming platforms continually increases, allowing retro gaming platforms to function beyond the original specifications set for them.

Through the continued efforts of fan communities play-only videogame interfaces have been extended through custom tools including emulators, custom development tools, and the creation of new hardware retrofits to become open creative canvasses for the production of music, graphics, animation, interactive art, and new gameplay experiences.

The arcade videogame's interface is shaped by era specific technical constraints that set the parameters for the aesthetic experience in terms of gameplay and audiovisual look and feel. These constraints provide valuable focus points, resulting in a signature style synonymous with retro gaming. The arcade videogame interface aesthetic endures, not just within the realms of gaming and its associated digital creative movements, but as a staple of contemporary pop culture.

## JAMMA: ERA, INTERFACE, PLATFORM, AESTHETIC

---

The following chapter is part historical, part technical, and part design orientated, and provides an overview of the JAMMA arcade hardware standard as a machine-to-machine interface, a family of platforms, and as an aesthetic of arcade gaming associated with the mid-1980s to late-1990s era.

It starts by exploring the origins of the JAMMA hardware standard as introduced by the Japan Amusement Machinery Manufacturers Association in 1985, including a timeline of its design and implementation process. This is followed by a technical summary of the JAMMA wiring standard, and the positing of the JAMMA standard as an interface and platform.

Innovations and augmentations of JAMMA standard hardware are also detailed, with particular focus on the Capcom CPS-1 hardware that powered *Street Fighter II* that led to the revival of the arcades in the early-1990s. Pirate arcade boards are also discussed, alongside JAMMA SuperGun systems aimed for home use.

This is followed by an overview of JAMMA adaptor variants and PC-based systems. This selection spans past, current and emerging technologies that enable the harnessing of the 1985 JAMMA standard by game modders, videogame artists, and indie game developers outside of the commercial arcade space.

The chapter concludes with a summary of the findings and a brief assessment of the future of the JAMMA standard as a platform for the arcade industry as well as for independent game developers and artists.

### 4.1 JAMMA THE TRADE ORGANISATION

JAMMA, the Japan Amusement Machinery Manufacturers Association, was originally set up as an industry rights group in 1981, before expanding its role to a trade organisation in 1989 [14, pp. 139]. Its members included industry leaders such as Sega, Namco, Sammy, Bandai, and Taito. However its remit included the interests of the arcade amusement industry in Japan as a whole, not just exclusively

those of videogame manufacturers.

'The JAMMA philosophy' as outlined in the English language section of the official website from 1998 through to 2018 outlines the organisation's commitment to 'Creating Communication Through Amusement':

"The goals of the Japan Amusement Machinery Manufacturers Association include promotion of the development of the industry through such activities as researching the environment surrounding the industry, development of technology, accumulation and presentation of information, promotion of exchanges with related entities both inside and outside Japan, and encouraging like minds to communicate through amusement facilities that reflect our times and environment.

In particular, recent activities of the Association include a wide variety of efforts in international exchange, elimination of counterfeit products, surveys and research and promotion of health" [139].

On April 1st, 2012 the JAMMA organisation incorporated the Japan SC Amusement Association (NSA) and the All Japan Amusement Park Association (JAPEA), changing the JAMMA acronym to represent the Japan Amusement Machine and Marketing Association, Inc [82].

In 2018 JAMMA underwent a further evolution, merging with the All Japan Amusement Faculty Business Association (AOU) on April 1st to form JAIA [83], the Japan Amusement Industry Association [81].

#### 4.2 JAMMA STANDARD: A HARDWARE-TO-HARDWARE INTERFACE

The JAMMA organisation developed the JAMMA wiring standard in 1985 in response to the need to standardise the technology connecting arcade game boards to their host cabinets, [14, pp. 139]. It is a standard born out of financial necessity, defining a common hardware-to-hardware interface link [10, p. 118-119] among the majority of arcade videogame cabinets and game PCBs from the mid-1980s onwards.

Tominak [174] compares the standard's significance to the RS-232 serial port, a standardised serial communications port introduced by the computing industry in 1960 that remains in use to this day [56].

In interview with Takashi Nakamura (2016), Koichi Tashiro of Namco, programmer of *Galaxian*, details that the JAMMA connector was in-part influenced by Atari hardware:

“It’s standardised based on the ATARI connector. The ATARI connector’s power is AC, then we changed it to DC” (T. Nakamura, pers. comm., September 16, 2016) [130].

It’s highly probable the connector referred to from the Atari System 2 system used by Atari from 1985 to 1987, an early attempt at modularised arcade hardware. It ran on AC power and used a 40-pin edge connector to join the ‘cartridge’ game PCB to the logic PCB [26].

Although the standard is referenced in operation and repair manuals issued by the arcade industry for their game boards and cabinets, there are no official design documents kept on the initial JAMMA design by the organisation, due to a combination to the pre-digisation time period, multiple relocations, and complete restructuring of the JAMMA organisation in 2012.

However technical documentation published in 2000 on the JAMMA organisation website<sup>5</sup> for revision 3 of the JVS (aka JAMMA 2) arcade standard<sup>6</sup> marks November 26th 1985 as the introduction date for the original JAMMA standard [40, p. 13] (Figure 3).

<sup>5</sup> Retrieved via the Internet Archive’s ‘Wayback Machine’ of cached website snapshots.

<sup>6</sup> JVS Revision 3 was released on May 31st 2000.

Q 7.7: What is the relationship between JS and JVS provisional periods?

A 7.7: Relationship between JS and JVS provisional period

Q 7.7 : JSとJVSの暫定期間の関係はどのようになりますか？

A 7.7 : JSとJVSの暫定期間の関係

	1985/11/26	1996/11/15	2000/1/1
JS		* 規格適応期間	
JVS STEP 1		* 規格適応期間	
JVS STEP 2		** 規格推奨期間	* 規格適応期間

\* Standard application period

\*\* Standard recommendation period

Figure 3: Official timeline detailing the introduction of the original JAMMA standard and JVS (aka JAMMA 2) versions 1 and 2.

Furthermore, the archives of Game Machine magazine from 1985 and 1986 provide an invaluable resource documenting the development of the JAMMA standard. Digitised in 2019, these issues include reports from JAMMA organisation meetings that outline the rationale

and process behind the PCB board standardisation move, in addition to technical diagrams from the final approved document (Figure 5).

#### 4.3 JAMMA STANDARD: DEVELOPMENT TIMELINE

The development process of the JAMMA standard from beginning to end took less than two months, from the first meeting on 15 October 1985, to the official approving of the JAMMA standard at the 28th JAMMA board of Directors Meeting on 26 November 1985 [111, p. 12]. This rapid turnaround was a considerable organisational and technical achievement by the team led by Tetsuo Fukuda, and is summarised in the following timeline:

- 15 OCTOBER 1985:

The ‘JAMMA Standards Settings Conference for TV Game Machine Boards’ [110, p. 3] was held at the TBR Building in Nagata-cho, Tokyo, with the aim of “reducing the burden on the operator” [109, p. 4], and also with a view to enhancing electrical safety. During this conference the ‘PCB JAMMA Standards Technical Committee’ was established. [109, p. 4]. Tetsuo Fukuda (Data East) was appointed as Chairman of the committee with Michihiro Saito (Taito) as Vice-Chairman, with the group comprised of technical staff from Data East, Taito, Namco, Sega, Nihon Bussan, Capcom, and Irem. The committee set about finding a solution to unifying their “edge connectors, board size, screen display direction, input / output signals, etc.” [109, p. 4].

- 29 OCTOBER 1985:

The first meeting of the PCB JAMMA Standards Technical Committee, resulting in the initial draft of the JAMMA Standard [110, p. 3].

- 7 NOVEMBER 1985:

Meeting two of the PCB JAMMA Standards Technical Committee, producing the second draft of the JAMMA Standard [110, p. 3].

- 14 NOVEMBER 1985:

Third meeting of the PCB JAMMA Standards Technical Committee, with draft three of the JAMMA Standard written [110, p. 3].

- 21 NOVEMBER 1985:



The second ‘Standardisation Conference’ was held (Figure 4a). During this meeting the technical committee agreed on the standardised parts and materials for JAMMA standard edge connectors and PCB boards, the JAMMA logo and placement, and the accompanying technical documentation [110, p. 3].

- 26 NOVEMBER 1985:

The JAMMA Standard was officially established at the 28th JAMMA Board of Directors Meeting held at the TBR building in Mizutamachi, Tokyo (Figure 4b):

“the “PCB JAMMA Standard” was established on the same date and decided to be implemented on January 1, 1986. The label for “JAMMA standard products” was decided to be 5 yen per sheet” [111, p. 12].



(a) JAMMA Standards Conference, 21 November 1985.



(b) The 28th JAMMA Board of Directors Meeting, 26 November 1985.

Figure 4: JAMMA organisation meetings. Image source © Game Machine Magazine issue 275, page 12, 1 January 1986.

- 1 JANUARY 1986:

The JAMMA Standard was “brought into force at the beginning of 1986” [129, p. 4], with the JAMMA Standard technical specifications published in issue 275 of Game Machine [84, p.16-17] (Figure 5). JAMMA president Masaya Nakamura outlined the advantages of the new standard in his 1986 New Year message:

“As you know, the current video game distribution is dominated by board sales, and game software is consumed quickly, so users are frequently replacing boards. If the standard of the board to be shipped is unified with the cooperation of each manufacturer, the advantage on the operator side will be greatly expanded, and the operation of the Electrical Appliance and Material Control Law will also be positive” [129, p. 4].

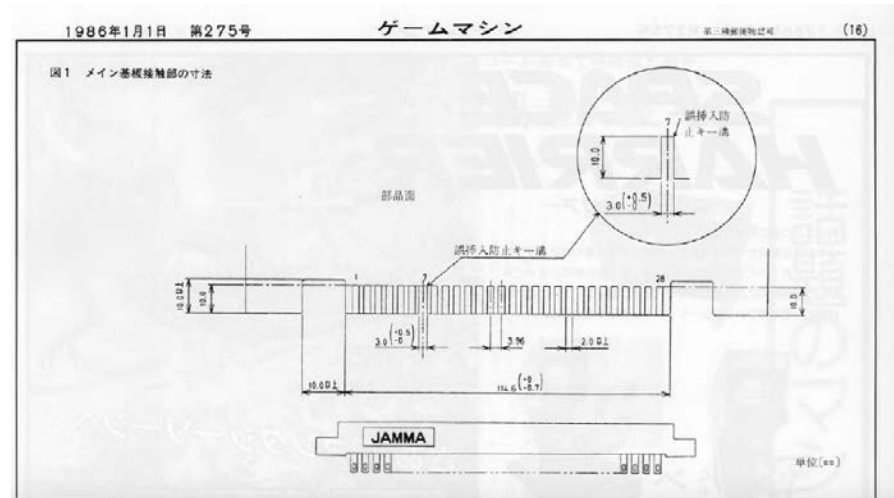


Figure 5: JAMMA Edge Connector Technical Schematic. Image source © Game Machine Magazine issue 275, page 16, 1 January 1986.

#### 4.4 THE JAMMA ERA

The JAMMA standard was gradually adopted by the industry, with several JAMMA consortium members publishing on their remaining non-JAMMA arcade hardware during 1986, and even during 1987 with the release of *Hissatsu Buraiken* aka *Avenger* on Capcom's Section Z hardware<sup>7</sup>.

<sup>7</sup> The Section Z hardware is named after its launch title, Section Z (Capcom, 1985). This follows a trend where arcade hardware typically used the name of the first published game as the system name.

As a standard born in the mid-1980s, JAMMA can also be interpreted as a blanket term for arcade audiovisual and gameplay aesthetics of the period, even if the host hardware didn't natively use the JAMMA standard connection. For example, IREM's M62 arcade board was introduced in 1984 and had games published on it until 1986 [28], but crosses over in terms of timeline, technology, and aesthetics with similar Z80-based JAMMA compatible boards.

#### 4.5 JAMMA AS A PLATFORM

Situating the JAMMA standard within Platform Studies pushes the area into boundary territory. JAMMA is unique since the baseline specification does not have a computational element per se. Rather it is a set of constraints in terms of basic control scheme and resolution that applies to a broad, and indeed ongoing, range of computational standards.

A bare JAMMA arcade cabinet or SuperGun without an attached game board has no CPU or computational aspect, yet imposes a set of baseline constraints on the host arcade PCB, including a 240p display,

mono sound, 2 joysticks with 3 fire buttons per player, a standard coin mechanism, and player start buttons. These parameters set by the JAMMA specification shape and mould the JAMMA aesthetic in terms of audiovisual and experiential feel and fidelity.

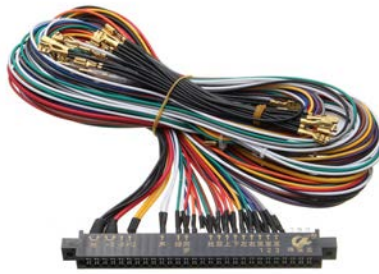
#### 4.6 JAMMA TECHNICAL SPECIFICATIONS

A JAMMA standard connection consists of a 56-pin edge connector with 28 double sided spaced at 0.156 inches, male on the game board (Table 1) [18]<sup>8</sup>. The spacing of these pins is consistent across all JAMMA boards. Arcade boards function as standalone computers, connected to the input and outputs of the game cabinet (Figure 6a) through a JAMMA wiring harness, also known as a JAMMA loom (Figure 6b).

<sup>8</sup> I and O are omitted to avoid confusion with the numbers 1 and 0. Similarly G and Q are not used as they resemble GND (ground).



(a) JAMMA compatible PCB with the 56-pin connector shown at the top.



(b) JAMMA wiring loom.

Figure 6: JAMMA compatible game board and wiring harness.

JAMMA standard arcade boards are exchangeable between machines conforming to the standard in a similar manner to the swapping of game cartridges on home console systems. The non-standard pin and connector sizes that are incompatible with pre-existing off the shelf components can be interpreted as a type of copy protection method, but also play a role in adding necessary durability for repeated use. However, most JAMMA boards do not include an obvious, error-proof one-way plug system, and if they are plugged in upside down the effects are often destructive to the game circuitry. Beyond the 56-pin interface, the platform specifications for videogame hardware using the JAMMA connection vary greatly in terms of memory, processing power, GPU type and sound playback technologies.

The uniformity in game cabinet connectivity introduced by the JAMMA standard reduced running costs for arcade operators, decoupling the mandatory purchase of a new physical cabinet for each new game title, instead allowing the reuse of existing game machines with new boards.

#### 4.6.1 JAMMA Augmentations

JAMMA+ (also known as JAMMA Plus) is a catch all term used to refer to adaptations of the original JAMMA standard that expand beyond three action buttons for each player. These additions are made at individual manufacturer level to support custom wiring needs. For example, SNK's Neo Geo system extends the JAMMA standard from three action buttons per player to four [93].

Additionally, JAMMA+ includes external wiring harnesses used in conjunction with the standard JAMMA edge connector, such as the sub-harness from Konami's simultaneous four player arcade brawler *The Simpsons* (1991), and the kick harness used for *Street Fighter II*.

The standard JAMMA harness can also be modified to accommodate extra button presses for players one and two by using both sides of non-connected pins 25 and 26, and both sides of ground pin 27 (Table 1).

In the 2000s Chinese manufactured JAMMA boards such as the Pandora Box PCBs have used variations of this modification to the JAMMA standard to support six buttons per player in fighting games without the need for a kick harness [2]. This non-standard rewiring of the JAMMA edge-connector is referred to by the unofficial shorthand of CHAMMA (Chinese JAMMA) [51]:

"I've been using the term since the early 2000's to describe the Chinese import boards that look and are super close but are not JAMMA compliant . . . Recently since the Game Elf and Pandora's Box started showing up, they cram 6 buttons per player on edge connector by stealing pin 27 and pin e for controls instead of the JAMMA standard ground for those pins. This requires an adapter to 'fix' them to JAMMA compliance, or rewiring a cabinet to play them" (Mike from mikesarcade.com, pers. comm., November 12, 2019)".

SOLDER SIDE				PARTS SIDE			
GND	A	1	GND				
GND	B	2	GND				
+5	C	3	+5				
+5	D	4	+5				
-5	E	5	-5				
+12	F	6	+12				
Key (no pin)	H	7	Key (no pin)				
Coin Counter 2	J	8	Coin Counter 1				
Coin Lockout 2	K	9	Coin Lockout 1				
Left Speaker (-)	L	10	Left Speaker (+)				
Right Speaker (-)	M	11	Right Speaker (+)				
Video Green	N	12	Video Red				
Video Sync	P	13	Video Blue				
Service Switch	R	14	Video GND				
Tilt	S	15	Test Switch				
Coin 2	T	16	Coin 1				
2P Start	U	17	1P Start				
(TB: H-Dir) 2P Up	V	18	1P Up (TB: H-Dir)				
(TB: H-Clock) 2P Down	W	19	1P Down (TB: H-Clock)				
(TB: V-Dir) 2P Left	X	20	1P Left (TB: V-Dir)				
(TB: V-Clock) 2P Right	Y	21	1P Right (TB: V-Clock)				
2P Button 1	Z	22	1P Button 1				
2P Button 2	a	23	1P Button 2				
2P Button 3	b	24	1P Button 3				
2P Button 4 (NC)	c	25	(NC) 1P Button 4				
2P Button 5 (NC)	d	26	(NC) 1P Button 5				
2P Button 6 (GND)	e	27	(GND) 1P Button 6				
GND	f	28	GND				

Table 1: JAMMA Pinout. TB = alternative trackball wiring. Note that the buttons on non-connected pins 25, 26, and ground pin 27 are a non-standard extensions of the JAMMA wiring scheme.

#### 4.7 JAMMA CASE STUDY: STREET FIGHTER II

Capcom's *Street Fighter II: The World Warrior* (1991) is credited as the game that brought a renewed interest in arcade gaming after a stagnant period in the latter half of the 1980s due to increased competition from the home videogame market [105]. *Street Fighter II* is also notable because it popularised one of the first workarounds to the limitations of the JAMMA standard, the kick harness used to connect extra buttons direct to the game PCB. Unlike the JAMMA standard, kick harnesses are not a universal wiring configuration. For example, the kick harness for *Street Fighter II* is incompatible with the kick harness used for *Street Fighter Alpha*.

Many early JAMMA compatible arcade platforms such as the Capcom CP System / CPS-1 (1988) feature a two PCB design, with both boards connected by ribbon cables. In this case one board is the computational side, while the other contains the game ROMs. This design consideration was made to reduce costs down further for arcade operators, though generally both boards are sold together for convenience [49], as the computer side is of little worth without a game to run on it.

The CPS-1 is powered by a 10 MHz Motorola 68000 CPU that doubles as the graphics processor and a secondary Zilog Z-80 running at 3.579 Mhz. The CPS-1 has two audio chips, a Yamaha YM2151 for 8 channel FM synthesis, and a MSM6295 providing 4 channel PCM voice for sample playback [27].

##### 4.7.1 *Street Fighter II* JAMMA bootlegs

To the playing public there are no differences in the game experience when playing an unmodified bootleg arcade games, bar perhaps an altering or removal of the publisher credits. However upon visual inspection bootlegged CP1 boards are obvious, made distinct by their lack of manufacturer labeling and cramped PCB layouts using generic components. Bootleg arcade boards such as the *Street Fighter II* variations are widespread because of their cheap price. Since there were no exclusively licensed chips used in making up the original CP-system arcade board, it was easy for the bootleggers to reverse engineer the designs using chips such as the Motorola 68000, while producing their own pirate versions of custom chips such as the system BIOS.

Going beyond the reverse engineering of BIOS chips and duplication of ROM sets, the modified bootleg editions of heavily pirated

1990s arcade titles such as *Street Fighter 2: Rainbow Edition* by Hung Hsi Enterprise Taiwan (c.1992) exist as combinations of fan service and black market entrepreneurship. These bootlegs proved popular to the extent that they directly influenced the development of *Street Fighter Turbo II - Hyper Fighting* (1992) and subsequent editions. Gameplay innovations adapted by Capcom from the bootleg editions include the adding of a fireball attack to Chun-Li's fighting repertoire, and the ability to perform special moves in mid-air [105].

#### 4.7.2 *Capcom CPS Changer System*

Capcom also introduced a home version of their CPS-1 hardware aimed at the home market called the CPS Changer System in 1994 [171]. Also called the Capcom Power System Changer, the system was sold through mail order and was met with limited success. Games sold for the CPS Changer were ordinary CPS-1 boards packaged in plastic shells resembling oversized console cartridges. The high cost of the system led to poor interest at the time of its release, as near arcade perfect ports of *Street Fighter II* and other CP System titles were available at substantially cheaper prices for home systems such as the Nintendo Super Famicom and NEC PC Engine.

### 4.8 THE SUPERGUN CONSOLISED JAMMA SETUP

Capcom's CP1 demonstrates that it's possible to use the standard JAMMA wiring scheme to play arcade PCBs without enclosing the circuitry in a full-size arcade cabinet. The only drawbacks are the space-management and cosmetic issues, caused by the wire spaghetti of the JAMMA loom and its associated input and output connections. A solution to these issues is build a JAMMA circuit into a small custom enclosure. Such systems exist in both DIY and professionally fabricated forms, and there are a few different names used to refer to these cabinet-less arcade setups, depending on country and context.

#### 4.8.1 *SuperGun Terminology*

Arcade operators and repair shops use JAMMA test rigs to troubleshoot and maintain PCBs, while in Japan consolised JAMMA units are commonly referred to as Control Boxes (or CBOX) [57]. Beep Game Centre traces the first professionally released JAMMA Control Box to Japanese game PCB retailer Kyowa International, [17]. The German equivalent is called a MAK (Mega Arcade Konsole), with the original MAK made by Wolfsoft in 1993 [112].



The SuperGun name originated in 1991 from a commercially manufactured JAMMA Control Box from Hong-Kong called the 'Super Gun II'. The logo for this product was a visual play on the Street Fighter II logo, with the 'Super Gun' name influenced by new reports from the first Gulf War [17]. SuperGun has since remained as a universal label for JAMMA compatible home arcade systems regardless of who has made the unit [164].

#### 4.8.2 *SuperGun Technical*

The SuperGun MAK Strike by Arcade Forge (Figure 7a) rests at the high end of the market in terms of its build quality. It allows the connection of a standard PC ATX power supply or an adjustable arcade PSU. A numeric LED displays a voltage reading, allowing easy power adjustment for non-standard PCBs.

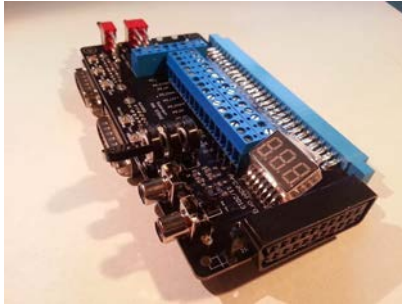
Connectivity wise it supports the unofficial 6 button per player extension of the JAMMA wiring harness. The MAK Strike also uses two DB-15 joystick ports, compatible with the SNK Neo Geo joystick configuration, in addition to a strip connector allowing the direct wiring of game controls. DB-15 is a common standard for generic, non-mass manufactured arcade control cables, since the connector in question isn't patented by any videogame manufacturer. Audio and video out are consolidated through an RGB SCART socket, while miniature buttons for selecting the number of players and inserting credits are included directly on the PCB, negating the need to include these on the attached game controllers.

The PanaTwin MP-92 SuperGun (Figure 7b) offers similar functionality while including a full size two-player arcade control panel, supporting 6 action buttons per player through a Capcom CPS compatible kick harness. The device also includes an additional set of control buttons for playing Mahjong games.

#### 4.8.3 *Scanline Generators and RGB Amps*

SuperGuns are often augmented by the addition of scanline generators and RGB amps. Scanline generators recreate the CRT display aesthetic on modern high definition displays, allowing the pixel graphics to be experienced as the artists had originally envisioned. On classic systems the colour bleed of the analog cathode ray tube was often harnessed as a graphics filter by artists, allowing them to increase the colour palette limits of their given platforms by using the imperfections of phosphor blur to optically mix the pixel hues. The sharpness





(a) Arcade Forge SuperGun MAK Strike. Image © arcadeforge.net.



(b) Pana Twin MP-92 Mahjong compatible SuperGun. Image CC-BY-NC-SA wiki.arcadeotaku.com.

Figure 7: JAMMA compatible SuperGun devices.

of modern displays allows great clarity, but also sanitises the rough pixel edges beyond what was intended at the time. Scanline generators reinstate this colouration and the intended visual vintage that characterises classic gaming.

#### 4.9 CONSOLE TIMER BOARDS

Home videogame consoles have also been brought to the arcade space through the use of non-sanctioned JAMMA adaptors. For example, an Xbox 360 to JAMMA adaptor allows direct connection of an Xbox 360 console into a JAMMA compliant arcade cabinet. A timing chip controls the amount of time the console is accessible for each coin token, resulting in a gaming experience that's commerce based rather than dictated by the players own skill. Console timer boards also overlay visual feedback onto the video signal when the time limit has nearly expired in the form of a text based overlay prompting the user to insert more credits.

#### 4.10 ARM-BASED MULTI-GAME BOARDS

Multi-game boards such as the generic 160-in-1 compilations and Pandora's Box compilations are ARM-based android systems running modified versions of MAME. The bootlegged ROMs featured usually have all manufacturer and copyright details edited out. These game boards are sold as closed systems, but often use standard SD card memory storage, and so are easily modified, in terms of both the menu screen appearance and the game titles included. Their use of VGA and HDMI display ports and direct DC power connections allow relegating the JAMMA harness solely as a control interface. They

are an affordable method of accessing older arcade titles and are ideally suited for retrofitting into restored cabinets.

#### 4.11 THE SNK NEO GEO AES AND MVS SYSTEMS

Although SuperGun consoles compact the JAMMA form to as small a form factor as possible, one aspect that they cannot miniaturise are the game PCBs. While circuit boards have plenty of interesting visual features, their aesthetic does not necessarily translate to the living room. One JAMMA variant that doesn't have this issue is the Neo Geo MVS [147] as it uses oversized plastic game cartridges. SNK's Neo Geo in was released in 1990 as a premium home system (AES) and an arcade platform (MVS) simultaneously. Both systems have the same hardware specifications, although the MVS cartridges use a different pinout to the home version.

High collector demand has meant that the prices for Neo Geo systems remain high, with mint condition copies of the rarest titles for the AES home console such as *Capcom Vs SNK: SVC Chaos* reaching extortionist prices of over €1000 [151]. The MVS games run same code, but are significantly cheaper, which has led to a demand for consolised versions of the MVS that house the MVS with a small SuperGun adapter inside a custom casing. Analog Interactive's 2011 CMVS Slim, a consolised MVS, mimics the AES form factor in a unique wooden shell [114].

#### 4.12 EARLY PC-BASED JAMMA HARDWARE

Since the mid-1990s PC compatible hardware has become a mainstream part of arcade hardware design, just as it has gradually infiltrated the console movement. In the late-1990s, Microsoft released XNA, a framework for accelerated 3D graphics that made PC systems a viable arcade gaming platform. This sparked the transition of the PC compatible from an office orientated platform to a true multimedia platform, leading to the adoption of PC architecture for arcade hardware installation.

In 1994 *Zool* by Gremlin Graphics was the first PC game that was ported to the arcades. The *Zool* arcade system ran a JAMMA compatible 486 system manufactured in the UK in 1994 by ATD / Attention To Detail and Bell Fruit Manufacturing [50]. However the system remained at prototype stage and did not see release beyond initial promotional appearances in the gaming press [8].

Taito's *Wolf System*, released in 1998 for the game *Psychic Force 2012* [29], is a JAMMA compatible arcade hardware board built on PC technologies, running a 200 Mhz Pentium MMX processor and the 3Dfx Voodoo Graphics chipset. The graphics accelerator and computational platform parts of the hardware are built on separate boards that are stacked and linked with Molex connectors. (Figure 8).

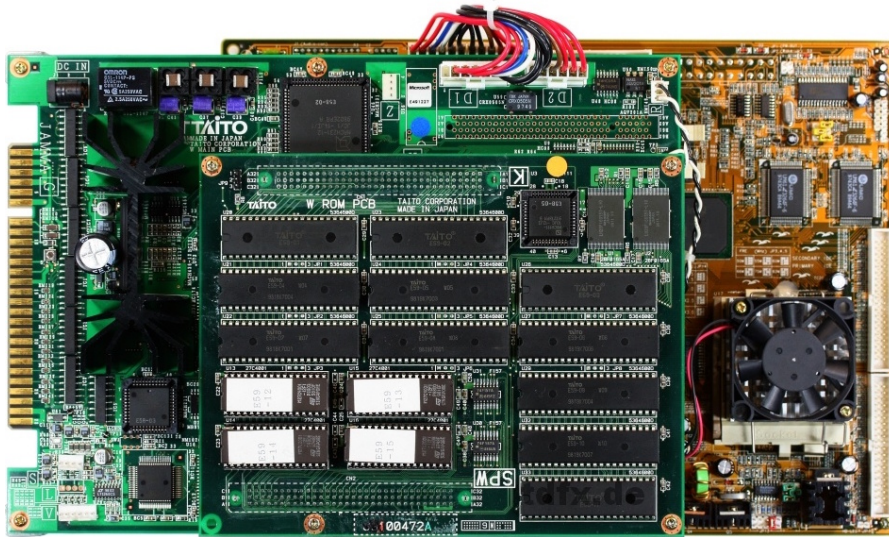


Figure 8: Taito's Wolf System Hardware. Image source: [http://tdfx.de/eng/arcade\\_wolf.shtml](http://tdfx.de/eng/arcade_wolf.shtml)

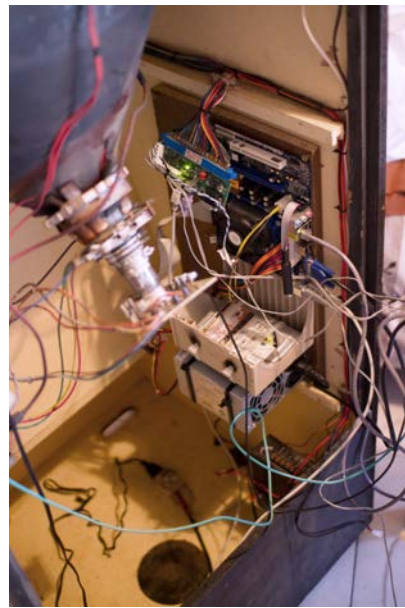
As arcade development has moved from bespoke computational hardware to standardised PC hardware, so too has their software side gravitated from custom development suites to 3rd party, cross-platform tools. *Street Fighter V* (2016) is powered by the Unreal engine, a departure for Capcom who built the series on their own tailor-made hardware and software technologies.

#### 4.13 SINGLE-BOARD COMPUTER JAMMA SYSTEMS

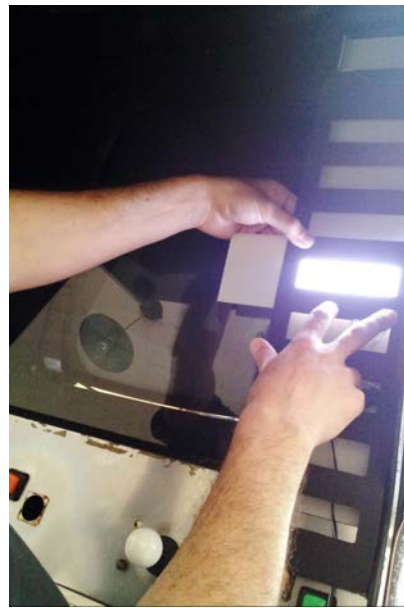
Since its introduction in 2012 the Raspberry Pi single-board computer has proved extremely popular among retro gaming enthusiasts because of its cheap price (€35) and the way availability of emulation software for it, including MAME and RetroPi. Raspberry Pi to JAMMA adaptors such as the Pi2JAMMA [182] equip the board with full JAMMA connectivity and represent a convenient option for both refurbishing original arcade cabinets and building replicas. The Raspberry Pi also provides an accessible platform for independent game developers who want to develop homebrew JAMMA compatible titles.

## 4.14 PC-BASED MODERN INDIE JAMMA ARCADE

Indie arcade developers have also harnessed PC systems inside arcade cabinets. Argentinian indie coin-op *NAVE* by Videogamo [73] was programmed in Adobe Flash, runs on a Windows XP system, and is fitted inside a customised JAMMA cabinet using a PC to JAMMA adaptor (Figure 9a). The *NAVE* arcade cabinet uses custom LED feedback strips running along both sides of the vertically orientated screen (Figure 9b), reacting in time with gameplay to heighten atmosphere and expand the game's visual feedback beyond the boundaries of the monitor.



(a) *NAVE* PC to JAMMA connection.



(b) *NAVE* custom LEDs.

Figure 9: *NAVE* PC to JAMMA and custom LEDs.

*Skycursor* is a horizontally scrolling shoot em up (2015) for JAMMA arcade platforms. It runs at 320x240 resolution that is standard for the CRT screens in the most basic JAMMA cabinet setups. For cost reasons, the game is distributed using the custom Airframe JAMMA system (Figure 10a), which uses off the shelf PC components connected to a JAMMA convertor rather than custom ICs. The game is sold in a conversion kit complete with cabinet artwork that can then be installed onto a standard JAMMA compliant arcade machine (Figure 10b).

In a pre-release interview with *Retro Maniac* magazine the development team explained their reasoning driving use of a PC-based JAMMA system:



"the cost of producing a custom PCB for one game would be very expensive (over 2,000 dollars) and further limit the number of people that can play our game. Therefore, to keep costs low, *Skycursor* and its hardware will resemble a micro-computer that is JAMMA compatible" [149].



(a) The Airframe PC-based JAMMA system.



(b) *Skycursor* arcade cabinet.

Figure 10: *Skycursor* conversion kit and cabinet.

#### 4.15 POST-JAMMA: JVS (AKA JAMMA 2)

The JVS / JAMMA Video System (aka JAMMA 2) was introduced in 1996 as a successor to the original JAMMA standard [180]. It supports VGA resolution video through an RS-485 port, and separates audio, video, and game controls. JVS uses USB ports, but not the USB protocol, instead using the custom JVS protocol to control IO signals [85]. This computational layer separates JVS from JAMMA, expanding the system's options for use of extra controller inputs, force feedback, and use of custom peripherals without bespoke direct-to-board kick-harness style connectors.

The JVS protocol is openly documented [172], and has been reverse engineered for use in home brew projects including the open source TeensyJVS [184], a JVS standard IO adaptor based on the low cost Arduino Teensy microcontroller that enables connection of game controls to JVS systems including the Sega Naomi game board.

The JVS-PAC2 by Irken Labs allows easy connection of PCs running MAME to JVS cabinets [158], while Jammafier [104] enables use

of JAMMA standard game boards in JVS arcade coin-ops.

The complexity of the JVS standard may also have been implicit in the continued survival of the original JAMMA standard, due to the added technical layers of JVS in turn increasing costs and so lessening its ability to impact upon the pre-existing install base of JAMMA compatible systems, similar to the continued survival of the home DVD market despite the release of technically superior but more expensive Blu-Ray technology.

#### 4.16 THE JAMMA AESTHETIC

Even though the JAMMA standard has been superseded technically, for example by the JAMMA organisation's own JVS standard, the ubiquity of JAMMA game cabinets has meant it still remains in place over three decades after its launch. *Skycursor* exemplifies how a modern arcade release built within the visual aesthetics and control constraints of the JAMMA standard. In a 2015 interview with the *Ten Pence Arcade* podcast, Chris of the *Skycursor* developers Griffin Aerotech speaks of the staying authentic to a 1980s and 1990s arcade visual aesthetic (Figure 11), abstaining from the use of modern graphics filters on classic pixel art graphics:

"I wanted to make sure that everything in *Skycursor* was completely authentic . . . if you see an effects of something happening on the screen it's been hand pixelled on screen, dot by dot, frame by frame . . . no shortcuts, no computer effects" [117].



Figure 11: *Skycursor* in-game screenshot.

The low resolution and low framerate visual viewfield of JAMMA arcade cabinets alongside a baseline standard two player joystick based controls [174] form the essential constraints that shape the player experience of JAMMA platform hardware as introduced in the mid-1980s, to its continued present day usage as both a play experience for consumers and a publishing platform for game creators.

Phil Golobish from the Skycursor sees JAMMA mainly as a wiring standard but also a term associated with the experience associated with 1980s and 1990s era arcades:

"As for our definition of what JAMMA means as a standard, platform and set of constraints, that's a great question. For me personally (Phil), and considering this point in my life as I work on producing hardware for a brand new indie arcade game (Skycursor), it's simply a wiring standard. However, that simple wiring standard, which has been around for 20 years, means there's a sizable, yet obviously shrinking, install base of cabinets that conform to that standard. Therefore, if our game conforms, we can take advantage of that market and all the lingering passion inside its fanbase. Granted, the fanbase probably sees JAMMA as more than a wiring standard and when someone says, "It's a JAMMA game," I totally get a vibe for what they are referring to in terms of graphics, gameplay, emotion, etc" (P. Golobish, pers. comm., August 25, 2015).

The experiential aspect of arcade games is an essential part of their aesthetic experience, going beyond audiovisuals to encompass engagement with the imagination. The look and feel extends beyond the screen and controls to the cabinets design, marquee artwork, and the situated space of the arcade gaming centre itself.

#### 4.17 CONCLUSIONS

When considering the computation aspect of JAMMA standard hardware it can be seen as not just one platform but a family of platforms. It is a common architecture, so far as connectivity options, but greatly varies in its memory, processing, and GPU implementations.

The low resolution and low framerate visual viewfield of JAMMA arcade cabinets alongside a baseline standard two player joystick based controls [174] form the essential constraints that shape the player experience of JAMMA platform hardware as introduced in the mid-1980s, to its continued present day usage as both a play experience for consumers and a publishing platform for game creators.

The JAMMA standard doesn't require a licence, but it's not open source. It is a necessary gift to the arcade industry by the arcade industry, in the vein of the RS-232 serial port. Three decades on since its invention the JAMMA arcade standard continues to survive, resisting competing standards including its own evolutionary augmentations in the forms of JAMMA+ and JVS. JAMMA harnesses are ubiquitous in part because there are no custom chips needed to use the

harness. The ready availability of PC to JAMMA converters and ease of small scale custom PCB manufacturing ensure that JAMMA is increasingly more accessible as a creative platform.

The movement to preserve classic arcade games through emulation software such as MAME has led to greater understanding of the mostly undocumented development of early arcade software and hardware, and in turn has contributed to a rise in JAMMA compatible hardware, albeit mostly unlicensed, that will keep classic arcade collections operating.

JAMMA can be defined as a common architecture in terms of connectivity options, but is greatly varied in its memory, processing, and GPU implementations. It is a family of platforms. Without an attached game board, the baseline JAMMA wiring system can be seen as a type of patch or platform constrainer. The continued flexibility of hardware platform standards is what has allowed JAMMA arcade technology to follow an evolutionary path that continues to the present day. JAMMA has managed to stay relevant, remaining in everyday use alongside the JVS standard that was intended to replace it.

In no small part the efforts of indie developers, artists, bootleggers, and the collector communities have all contributed to the extension of the platform's functionality, aesthetics, and lifespan. Also, thanks to increasing accessibility of PC to JAMMA adaptors, developing for arcade standards has become an increasingly more viable option for independent developers.

Although they are built on systems technically exceeding the original JAMMA era platforms, *NAVE* and *Skycursor* adhere to an aesthetic of that age by using pixel art and audio aesthetics in-line with games of the 1980s and 1990s. The Japan Amusement Machine and Marketing Association's JAMMA standard has become the established arcade hardware-to-hardware interface worldwide, one accessible by both industry and indies alike.



## ARCADE: PLATFORM, MATERIAL, GENRE

---

This chapter focuses mainly on the aesthetic properties and production processes of arcade to home computer game conversions during the 1980s and 1990s, in particular arcade titles originating in Japan that were licensed by UK-based software houses for the 8-bit and 16-bit microcomputer market in Europe.

The arcade to home computer conversion teams detailed worked within the unique constraints of 6 main platforms, namely the ZX Spectrum, Amstrad / Schneider CPC, Commodore 64, Atari ST, Commodore Amiga, and MS-DOS PC. In all the examples discussed, the original arcade cabinet was used as the core audiovisual and gameplay reference.

As a human mediated process, the conversion of the digital material of coin-operated arcade games to home computers not only bore the audiovisual constraints of the target platforms, but also the creative signatures of the conversion teams. The most successful home adaptations succeeded in capturing the essence of the arcade originals, while positively augmenting the gameplay, narrative, and overall aesthetic.

The term arcade exists as a platform, a space, and a genre, embodied in both software and hardware. It can also be seen as a material, transmutable between forms through ports and conversions, whether from arcade to home, home to arcade, or the situating of home microcomputer-based games in arcade environments. Arcade even exists as an aesthetic outside of digital space through game art practice.

The platform fluidity of the arcade genre, alongside the technical and creative symbiosis between the home and arcade production practices and markets in the 1980s and 1990s, resulted in a dynamic that has contributed to the creative evolution of arcade gaming in its totality.

### 5.1 ARCADE CONVERSIONS AND COMPUTER BORN ARCADE

The arcade is not just a situated space where videogames are played, but in the context of home videogaming it also exists as a genre clas-

sification, or genre refiner. This usage as a classification changes depending on the time period, audience context and is defined by “players, journalist, and publishers alike” [106]. As with all genre classifications, it has a certain amount of fluidity. Additionally the criteria for genre classification are under constant debate.

When Nintendo launched the NES system in North America (1985), following the success of the Famicom (1983) in Japan, they used seven categories to describe their games based on the peripheral used and genre [7, p. 105]. Arcade is among this list. As a genre label it taps into prior knowledge assumed on behalf of (potential) customers [11, p. 354], communicating Nintendo’s intentional capitalising on the success of their best arcade titles such as *Donkey Kong* for their home market.

Issues of Commodore User magazine (previously known as CU Amiga / 64 and then CU Amiga) from the late 1980s and during the 1990s carries numerous examples of arcade used to describe games. These range from direct conversions of coin-operated arcade games, and for computer-born titles that boast to be either arcade-style, arcade-quality, or coin-op quality.

*Xenon 2* (1989) is a vertically scrolling shoot em’ up from UK-based development team The Bitmap Brothers and an example of a computer born arcade title that has been described using the aforementioned three labels. The back of the packaging for *Xenon 2* emphasises its closeness to the arcade experience (in gratuitous all-caps type):

“Xenon 2: HARD, fast COIN-OP QUALITY destructive action with a HOT soundtrack to match”.

The quality of arcade conversions on home computers at the time of *Xenon 2* varied greatly dependent on the system architecture, and the development process. Many coin-op conversions carried out by third party developers were done so without direct access to the original development kits or source files. This meant that even if the machine had an equivalent graphics resolution, the imagery was reinterpreted by the artistic skills of the pixel artist working on the port.

At the turn of the 1990s, the technology used in arcade boards was ahead of what most home computers could achieve. While Japan had the Fujitsu FM Towns and the Sharp X68000, the 16 bit PC technology in the west at the time was a generation behind in terms of multimedia capabilities. The Amiga was the head of the pack, followed by the Atari ST. The PC compatible then sported a multitude of configurations, staying behind in the race until accelerating ahead in the mid 1990s. Arcade conversions for pre-VGA graphics PC DOS systems

and 8 bit systems resulted in lo-fi reinterpretations of the originals, both due to graphical constraints and also whether the conversion team had direct access to the arcade source files.

The PC DOS version of *Double Dragon* (1988) features squelchy PC beeper sound effects and extremely basic graphics in comparison to the original, seemingly drawn from scratch rather than having been based upon original source files. Young audiences were happy to overlook technical shortcomings because the home versions afforded free play (after legal purchase of course) and the novelty of having an approximation of the arcade experience at home.

Searching for 'arcade' on Archive.org brings up games that are both arcade conversions such as *Super Street Fighter II* (1996), and computer-born arcade games like the slightly lesser well known *Trolls* (1992). Both are classified under the main genre of Action, with Arcade listed as a theme. Mobygames defines arcade as:

"Arcade refers not to games that originated as arcade machines, but to action games with very simple gameplay interaction similar to coin-op arcade games. These games usually require little puzzle solving or tactical thinking and rely solely on the "twitch" gameplay. Related sub-genres include Maze games and Paddle/Pong games" [126]

Arcade is used as a genre label throughout this thesis when referring to arcade style gameplay and also to arcade conversions on home system in fitting with the 1980s and 1990s influence of the study.

## 5.2 HOME COMPUTER TO ARCADE PLATFORM

In addition to the both arcade to home computer game conversions and computer-born arcade genre games, during the 1980s and 1990s games originating on microcomputers transferred over to the arcade space, as both rewrote adaptations and direct code and hardware system transplants.

The arcade version of *Boulder Dash* (1984) by coin-op manufacturer Exidy for their *Max-A-Flex* system takes an Atari 600XL computer running an unmodified home consumer version of First Star Software's *Boulder Dash* on cartridge and transplants both into an arcade shell. The arcade control panel features a three-segment LCD countdown timer. Gameplay duration is determined by the amount of credits deposited rather than skill, and offers the unusual dynamic of been able to continue a previous player's game [163]. In this case the coin-timer mechanism acts as a hardware-based patch for computer born

titles.

Irem's home computer to arcade conversions of Broderbund's *Lode Runner* (1984) and Micrographic's *Spelunker* (1985) are complete rewrites, fully harnessing the technical affordances of Irem's M62 arcade hardware [28], improving the graphical and animation levels of both game's character and stage design.

Arcade born titles have received exclusive spin offs on home platforms. UK-based software house U.S. Gold produced three home exclusive sequels to arcade titles. *Out Run Europa* (1991), developed by Probe Software in 1991, was a response to the 1987 sales success of the *Out Run* home conversions [178, p. 136], but was produced with little to no involvement from Sega [148]. *Human Killing Machine* (1989) is an unofficial sequel to U.S. Gold's home ports of *Street Fighter* released in 1989, although it reuses the engines to Tiertex's *Street Fighter* conversions, it has no other links with Capcom's fighting franchise. *Strider II* (1990), also produced by Tiertex, extended the original home port's engine. However it didn't resound with critics, and was wiped from series continuity by Sega's own *Strider 2* in 1999.

### 5.3 ARCADE TO HOME CONVERSION CREATIVE PRACTICES

The release roster for the home conversions of Capcom's *Forgotten Worlds* (1991) by UK-based game development and publishing studio U.S. Gold is representative of the European home computer market of the time, with ports of SF2 released across six main home platforms (Table 2). Three of these were 8-bit systems, the Sinclair ZX Spectrum, Commodore 64, and the Amstrad / Schneider CPC, each with cassette and diskette media options. The Atari ST and Commodore Amiga were the staple 16-bit target markets, with MS-DOS based PC compatibles gaining greater momentum in the early 1990s. This broad range of platforms, each with significantly different computational architecture, storage media, control systems, and audiovisual capabilities resulted in each arcade license undergoing multiple reinterpretations.

Developer interviews with the teams behind the home conversions of *Forgotten Worlds* (1989), *Rainbow Islands* (1989), *Midnight Resistance* (1990), *Snow Bros* (1991), and *Mercs* (1991) from sources including *The One* and *Commodore User* magazines each detail the use of the original arcade cabinets as the main reference material, rather than reliance purely on provided digital assets and design documents.

PLATFORM	CPU	RAM	GRAPHICS	SOUND	STORAGE
<i>Commodore Amiga 500</i>	16-bit 680x0, base 7.09 MHz and higher	512KB	64 colours onscreen max (EHB mode), 4096 (HAM mode), 320 x 256, 640 x 256, 640 x 512 (PAL)	4 PCM channels	3.5" 880kB floppy
<i>Atari 520ST</i>	16-bit 680x0, base 8 MHz and higher	512KB	16 colours: 320 x 240, 4 colours: 640 x 200, mono: 640x400	3 voice square wave, 1 voice noise	360kB, 360kb and 720kB 3.5" floppy
<i>IBM PC compatibles</i>	16-bit 8086 4 MHz and higher	64KB base*	256 colours max, 320 x 200 (VGA), 16 colours, 640 x 350 (EGA), 4 colours, 320 x 240 (CGA), mono, 720 x 348 (Hercules)	PC Beeper, sound card**	160kB, 360kB, 1.2MB 5.25" and 720kB, 1.44MB 3.5" floppy, hard drive
<i>Commodore 64</i>	8-bit 6510, 0.9852 MHz	64KB	16 colours, 160 x 200	SID chip, 4 channels	Cassette, 5.25" 170kB floppy
<i>Amstrad / Schneider CPC</i>	8-bit Z80A, 4 MHz	64KB, 128KB	16 colours, 160 x 200, 4 colour 320 x 200, 2 colours 640 x 200	3 channel square wave, 1 channel noise	Cassette, 360kB 3" floppy
<i>Sinclair ZX Spectrum</i>	8-bit Z80, 3.5 MHz	48KB, 128KB	256 x 192, 15 colours	Beeper (48KB), 3 voice FM synth (128KB)	Cassette, 360kB 3" floppy

Table 2: Comparison chart of technical specifications for the six main home computer platforms targeted by UK-based software houses, including Ocean, U.S. Gold, and Graftgold, in the late 1980s and early 1990s. \*IBM PCjr configuration. \*\*The AdLib Music Synthesizer card (1987) supported FM synthesis via a Yamaha YM3812. It was superseded in the market by the Sound Blaster (1989).

The referenced magazine interviews were originally published to stoke anticipation for upcoming releases, and are wrote in collegial tones, at times downplaying the limitations of the target systems. For example when discussing the redrawn graphics for *Forgotten Worlds* on the Amiga, South remarks:

“In some cases (including the close-up faces) the Amiga graphics are arguably superior” [160, p. 24].

Despite any platform-centric biases evident, as historical documents the developer interviews provide valuable records of the creative, technical and business processes undergone by the teams involved.

In interview with veteran game developer Jas Austin, Gazzard links the decline in production of arcade clones for British home micros in the mid-1980s with the beginnings of licensed arcade home conversions for the UK market [65]. This change coincided with mounting pressures placed on the industry by original arcade IP owners. Gazzard’s journal article also draws direct parallels between the development of arcade clones and official arcade to home ports, with copying from visual references forming the backbone of the production process for both game types.

The developers of each arcade to home conversion case considered in this paper laboriously recreated their source material by directly referencing the arcade screen. This process used eye to hand artistry to reproduce the game graphics, often augmented by the use of video camera-based frame capture units trained directly at the arcade cabinet’s CRT. By using video capture, additional visual aspects such as spatial distortion from the curve of the arcade monitor, camera lens distortion, capture device resolution, and file compression artefacts are combined with the artists own style, adding additional layers of graphical filtration.

Although the original developers were willing to assist the conversion team, the use of snail mail to distribute digital assets often clashed with deadlines, alongside issues of file compatibility, leading to the conversion team forging ahead with most if not all of their game graphics from scratch. The language barrier between Japanese and English speaking developers was also a factor, with the developers of the Amiga and Atari ST versions of *Rainbow Islands* (1989) reinterpreting the games music by listening directly to the coin op rather than translating the paper-based music notation supplied by Taito [140, p. 16].

When machine imposed storage and processing restrictions were combined with manual approximation of game logic and assets, the resulting home computer ports often had considerable aesthetic changes

from their original arcade source. These changes manifested not just in terms of the visual look and feel alongside the game audio, but also in terms of the gameplay flow and narrative.

### 5.3.1 Magazine Advertising: Arcade Authenticity and Approximation

A magazine advertisement by Image Works for their 1989 home conversion of *Blasteroids*, originally released for the arcades by Tengen in 1987, emphasises airbrushed artwork and an image of the original coin-op cabinet, with in-game screenshots sidelined to a column on the left of the page (Figure 12a). The copy boasts of the accurate reproduction home ports' gameplay features, "Straight from the arcades comes *Blasteroids*. Tengen's classic mix of one or two player action. With full power-ups, rip-stars, shields, double-up and more. This is the coin-op conversion of 1989" [140, p. 9].

The featured screenshots are from the Commodore Amiga version, the most graphically advanced of the home computer systems that *Blasteroids* was published to, yet the included screen captures are low quality and do not adequately convey the game's visual quality, hence the use of the airbrushed artwork as a selling point. As a supporting paratextual element, this hand rendered game artwork presents the idealised version of the game environment that supporting platforms of 1989 could not match.

Similarly the advertising copy for Ocean Software's home conversions of *Operation Wolf* relies heavily on airbrushed artwork, taglines, and reviewer praise to drive home to potential customers that the home versions of the arcade game capture the essence of the arcade experience (Figure 12b). *Operation Wolf* is an on the rails shooter, played in a stand up custom cabinet via an Uzi shaped controller. It was released across 5 main computer platforms for the European market, with a PC version developed and released by Taito for the North American market.

"Six levels of thrilling coin-op action brought to life on your home micro . . . [A]ll the original arcade play features - magazine reloads, energy bottles, hidden supplies, rocket grenades and more . . . much more!"

A quote from ACE magazine backing up this assertion is given a prominent typeface at the base of the page:

"Not only has all the action and gameplay been captured, but so has the excitement, making it one of the most satis-



(a) *Blasteroids* (Image Works, 1989).(b) *Operation Wolf* (Ocean, 1989).Figure 12: Magazine advertisements for *Blasteroids* and *Operation Wolf* (1989).

fying and compulsive shoot-em-ups to have appeared in a long time” [140, p. 83].

The featured screenshots are photographs of the arcade version, evident from the curve of the cathode ray tube screen and their colour palette. No images are shown of the advertised home conversions, hence the emphasis given to the reviewer endorsements. Bob Wake-lin’s airbrushed artwork takes centre stage, reworking the original game logo into a striking metallic 3D logotype, with the anonymous protagonist taking aim directly at the reader. The original Taito *Operation Wolf* logo is relegated to the lower left of the screen, under the arcade screenshots and cabinet image, such is the confidence of the home conversion’s identity.

When separated from the original coin-op hardware, *Operation Wolf* switches from playing in a stand up position with a custom Uzi gun controller, to using keyboard, joystick, or mouse in a (normally) seated position. The former two control methods create a greater level of difficulty as the player fights the crosshairs inertia. Lightgun support was included for later editions of the 8-bit computer ports bringing the home computer experience closer to the arcade original.

Despite the change of manual control device, each home release competently recreates the onscreen feedback mechanism of the arcade original’s heads up display. *Operation Wolf*’s HUD is notable for its communication of tension, with the depletion of each ammo



clip represented by a fast disappearing grid of bullet icons, separated from the periphery of the game field by a pulsing damage meter. The onscreen feedback of (Figure 13a) indicates high damage and three remaining ammunition clips.

The 8-bit versions made necessary adjustments to the onscreen layout to compensate for resolution differences and processing power, with the Commodore 64 port (Figure 13b) relocating part of the feedback HUD underneath the gameplay area. The HUD is expanded to run underneath the play area in order to create space for readable and recognisable low-resolution versions of the arcade icons. While the 8-bit graphics are manually redrawn rather than digitally downsampled from the originals, when presented alongside the HUD the overall composite view retains a look and feel easily linked to original arcade aesthetic.



(a) *Operation Wolf*, Arcade.



(b) *Operation Wolf* Commodore 64.

Figure 13: *Operation Wolf*: arcade original (Taito, 1987) and C64 version (Ocean, 1989).

### 5.3.2 1990s Game Advertising as Inadvertent Game Art

Elite System's 1990 magazine advertisement for their 16-bit home computer conversions of Capcom's 1985 arcade release *Ghosts 'N Goblins* [52] goes beyond screenshots, proudly displaying the game running on an Atari ST computer and monitor setup, alongside copies of the game packaging (Figure 14). This marks a departure from the norm of coin-op conversion marketing of the time, eschewing a combination of airbrushed artwork alongside a photographed image of the original arcade machine, and instead delivering a direct representation of the home product as hosted in its play platform, alongside the physical medium the software is distributed through.

The scene also features a diorama portraying the game's protagonist Arthur surrounded by ghoulish creatures, constructed from recognisable toys of the era including Masters of the Universe and Bionicles.

characters. While both are properties of Mattel, there is no reference to the company in the advertisement. As a tangibly modelled interpretation of an in-game environment, this scene can be viewed as an early, naive form of game art.



Figure 14: Detail from a 1990 magazine advertisement by Elite for their 16-bit home conversions of *Ghosts 'N Goblins*. A diorama (right) recreates the in-game world, accompanying the Atari ST conversion.

While the software and hardware platform manufacturers visual identities associated with this coin-op conversion feature prominently, the substantive technical and aesthetic variations between the Atari ST, Commodore Amiga, and IBM PC compatible conversions are not highlighted visually, but are mentioned in the accompanying text.

In terms of arcade accuracy, the Amiga and IBM PC versions are touted as featuring all of the original game levels, with the Amiga version featuring graphics taken directly from the original coin-op ROM, a plus point for arcade authenticity. Common links between all three formats and the coin-op original are 4-way scrolling (incorrectly stated for the PC version, which uses a flip-screen approach instead of scrolling), the amount of weapons and opponents, and the option of one or two player modes. Even though the advertisement states that the home conversions capture "every detail in true 16-bit style", it is fair to comment that these details are not common to each ver-

sion.

Although not displayed in the advertisement, the IBM PC version of *Ghosts 'N Goblins* falls at the lower rung of the ladder visually due to limited palette and low quality artwork. The Atari ST version occupies the mid-level, with redrawn but recognisable sprites and environments. On the spectrum from conversion to port, the Commodore Amiga conversion qualifies closer as a port. Materially it contains a direct injection of the arcade essence in the form of the original arcade graphic data, so existing in part as a direct transfer of the original than an approximation of all components.

### 5.3.3 *Forgotten Worlds* (1989)

The *Forgotten Worlds* (Capcom, 1989) home conversions were produced by Arc Developments for UK-based software house US Gold [160, p. 23-26]. *Forgotten Worlds* is a side scrolling shoot em up for simultaneous two player play, where the player characters main fly through space wearing rocket packs while wielding bazookas, fighting flying lizard aliens and giant dragons along their journey.

Arc developed all of the conversions in parallel over a brief a four month timeframe, with their process facilitated in part through a PDS (Programmers Development System). This kit allowed development in assembly language on an IBM PC connected to the target Z80 and 6502 processor-based platforms via a custom link cable. On the parallel development process, Arc team member Byron remarked:

"It works well, there's a lot of ideas going between machines. If you did it one version at a time you'd probably end up with one very good version . . . the first one. Then you'd get a bit bored, I think. It's better to get the job done in a few months and move on".

Arc were not provided with any source files by Capcom, leading the team to manually replicated the arcade machine visually, sonically, and in terms of gameplay. The arcade PCB was accessible solely as a play only device, with the game code and assets contained on the ROMs inaccessible to the developers. The only direct manipulation of the arcade game hardware was the addition of a pause switch through a hardware hack, which aided the development team in their task of studying gameplay patterns and on screen visuals.

A digital image capture setup was trained at the arcade monitor, using a video camera alongside Digiview Gold to capture the image for editing in Deluxe Paint. This image transference resulting in the

arcade graphics undergoing an initial four levels of filtering before been converted across to each target platform. This pipeline starts with the scanlines, reflection, luminescence, and curvature applied to the image through it's display on the cathode ray tube screen of the arcade machine. The second filter layer is added through the optics of the video camera used, with the limited colour palette and resolution of the Digiview and Commodore Amiga capture setup adding a third level of colouration to the image. The final filter level is added through the hand and eye of the artists tasked with taking the video captures and rotoscoping them into a consistent style.

Figure 15 demonstrates the change in visual style between the arcade original and the edited video capture on the Commodore Amiga. The accompanying commentary offers subjective encouragement from the reviewer to both the development team and prospective purchasers of the then upcoming release that the graphics were an improvement on the arcade original.

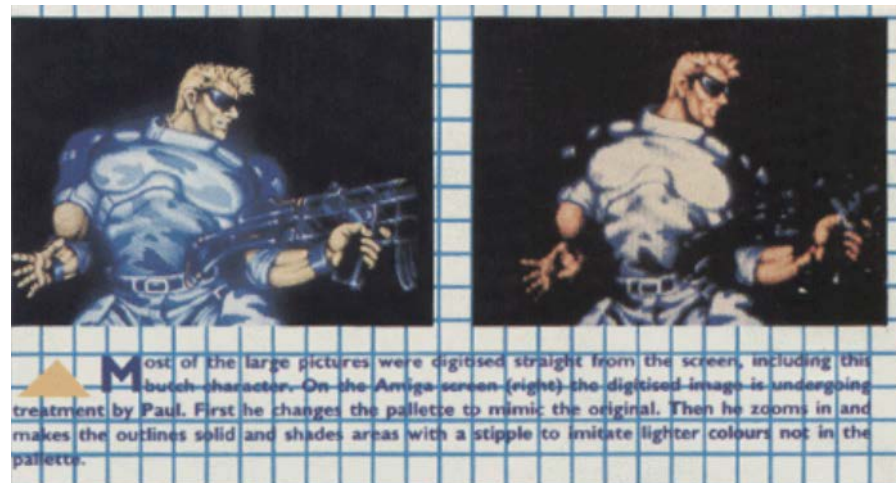


Figure 15: A comparison between the arcade screen capture (left) of *Forgotten Worlds* and the retouched version on the Commodore Amiga (right).

Some graphics were redrawn from scratch because of a lack of satisfaction with the screen capture source [160, p. 25]. An example of this is the mid-level shop stage (Figure 16a), although the difference in resolution between the arcade original at 384 x 224 and the Atari ST conversion at 320 x 200 (Figure 16b) is relatively small, the ornate fine lines of the pixelated metalwork details of the screen did not survive the transfer process, due to the distortion of narrow details through lens capture and low resolution digitisation, necessitating a complete redraw of the scene.

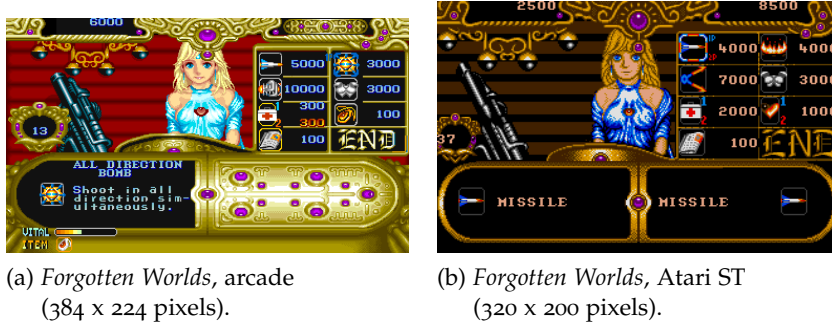


Figure 16: The shop stage in the arcade and Atari ST versions of *Forgotten Worlds*.

The redrawn graphics were limited to an eight colour palette, with a stippling effect used to increase the perceived colour depth where necessary, a technique that uses the refresh blur of CRT screens to optically blend duotone single pixel grids into a perceived third colour, with varying stippling patterns used to create multiple textures. All the reworked images were saved as Amiga IFF files format (International File Format, a standard devised by Commodore and Electronic Arts), and then converted to multiple systems using Arc's own custom software solution.

"The graphics have been sourced on an Amiga 500 and then ported to the destination machines. "This is one of the new things we've tackled with *Forgotten Worlds*" says Paul, "new ways of porting ten special converter routines to take the work out of converting Amiga IFF files to Spectrum, PC, ST, C64 and Amstrad formats, so with luck Paul only has to draw the graphics once" [160, p. 24].

The porting process for all music and sound effects follows a similar analog transferral process, with the arcade game audio recorded on cassette and then transcribed and re recorded for each target platform "It's a case of sticking a microphone in front of the machine and recording what comes out" [160, p. 26].

#### 5.3.4 *Rainbow Islands* (1989)

Graftgold's arcade conversion process for Taito's *Rainbow Islands* combined both direct reference of the arcade machine and the use of original media supplied by Taito in the form of image files in IFF format on PC formatted 3.5" floppy disks (figure 8). The Atari ST could read PC disks, but couldn't read the IFF file format. This instance is illustrative of the lack of interoperability between home computing platforms in the 1980s and early 1990s. The development team programmed a cus-



tom utility in STOS to convert the IFF files to Atari ST Neochrome graphics format (Figure 17). The images supplied included images that did not make it into the final game release.

“The graphics provided probably came from the designer, as some sprites simply weren’t present and so had to be drawn from scratch. There were also some extra frames of animation, such as Bub ‘surfing’ over the rainbows instead of merely walking. More amusing though, is a sequence where Bub takes all his clothes off and changes into a Superman outfit” [140, p. 16].

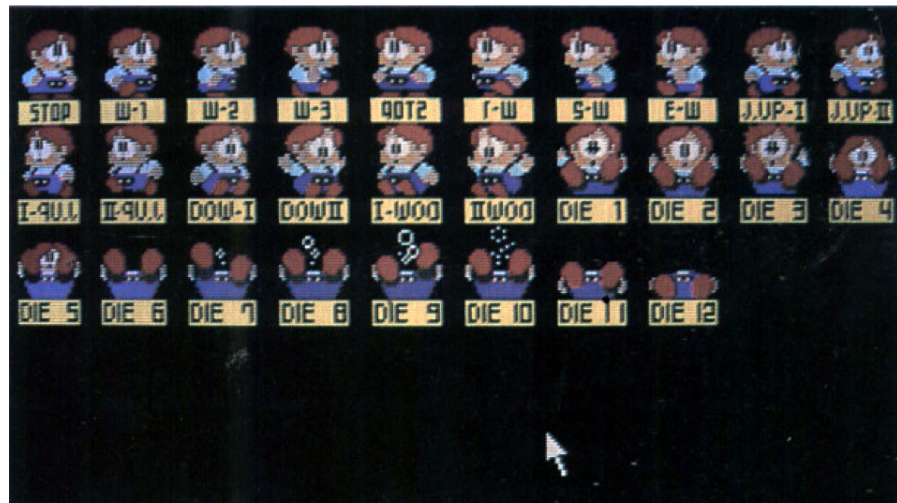


Figure 17: *Rainbow Islands* character animation frames.

According to Penn’s interview, approximately 50% of the game’s graphics were hand rendered using photographs and a video recording as reference material. Communication and language barriers between the arcade developers and the conversion team were also an issue, with the game’s music supplied in sheet music form with Japanese notation. With no access to a translator, the Graftgold team resorted to transcribing the music directly from the arcade machine.

Transferral of the gameplay mechanics and level structure to the home computer adaptations was made possible through extensive note taking of gameplay interactions and level maps. Team member David O’Connor asserts that his direct experience of the gameplay was a necessary addition to the provided paper-based documentation:

“We have to sit down and analyse the way creatures move and so on and try to recreate this. Taito provided a large booklet with the original game design rather than programming notes, so although we know who fires what

and at what speed things move, most of the information isn't that relevant to the arcade game as we know it." [140, p. 16].

The Atari ST (Figure 18a) was the initial 16-bit home computer platform to host a conversion of *Rainbow Islands*, with the Commodore Amiga version being a port of the ST conversion. The lesser powered Atari ST was used as the development machine for both graphics compression and decompression. The read speed of the disk drives for both systems were an additional constraining factor alongside the audio visual capabilities of the Amiga versus the ST, and so the game was optimised on lesser equipped ST first.

*Rainbow Islands* on the 8-bit platforms is effectively a demake, however the cartoon graphics style did convert across relatively intact to the Commodore 64, Amstrad CPC / Schneider (Figure 18b) and ZX Spectrum versions. The C64 version is characterised by a muted colour palette, with the ZX rendition compensating in detail for what it lacks in colour depth. The Amstrad version strikes a balance between the aforementioned two platforms, with graphics that are blockier than the Commodore 64, but capitalises on the saturated colour palette of the CPC.



(a) Atari ST version of *Rainbow Islands*.



(b) *Rainbow Islands* for Amstrad CPC.

Figure 18: The Atari ST and Amstrad / Schneider CPC conversions of *Rainbow Islands*.

Both the 8-bit and 16-bit versions share the same adjustment to the gameplay control scheme, with each system using a default 1 button controller. The original arcade incarnations of *Rainbow Islands* uses an 8 direction joystick alongside a jump button and a fire button. The home version use the solution of pressing up on the joystick to jump, which does not impede the gameplay and is an issue only for someone making the initial switch from the arcade version to the home computer port.

### 5.3.5 *Midnight Resistance* (1990)

Liverpool-based Special-FX produced the home conversions of Data East's *Midnight Resistance* for Ocean Software (1990). Special-FX used the arcade version of *Midnight Resistance* (Figure 19a) as their sole reference out of necessity, as the disks supplied to them by Data East containing the original graphics files became corrupted. The team used a video camera pointed at screen to record game footage to VHS tape, which was then referred to by the artist who redrew the graphics from scratch from this source [34, p. 52].

*Midnight Resistance's* Commodore Amiga conversion (Figure 19b) is the closest graphical approximation to the original (Figure 19a), retaining its simultaneous 2 player mode and scrolling playfield. However due to limited resources the HUD is no longer superimposed over the playfield. The Atari ST has a similar resolution but is limited to single player gameplay, and uses a flip screen system instead of scrolling.

The Commodore 64 conversion is recognisable but (naturally) rendered at a lower resolution to the 16-bit original, and both animates and scrolls smoothly (Figure 19c). However the ZX Spectrum (Figure 19d) and Amstrad CPC versions are particularly noteworthy due to their original reinterpretation of the game characters and environment in a style reminiscent of the Super Deformed / SD character design technique used in Japanese comics and animation.

By taking this decision to radically alter the games aesthetic, the ZX Spectrum and Amstrad versions of *Midnight Resistance* maximise the graphical constraints of their host platforms, rather than presenting watered down versions of the original.

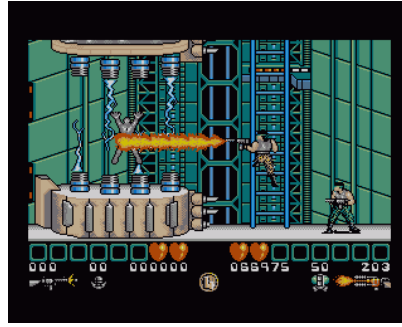
The triumph of the Special-FX *Midnight Resistance* ZX Spectrum conversion is celebrated in a magazine advertisement (Figure 20) placed in *The One* (1990), a multi format magazine with an emphasis on the 16-bit market. While the advert is for five main formats (with the DOS PC excluded), the 8-bit ZX Spectrum version is the focus of the promo, with the 'Crash Smash' reviewer accolade from the venerable ZX Spectrum magazine highlighted alongside the endorsement: "Graphics are very impressive . . . all sprites and backgrounds are beautifully detailed . . . more playable than its arcade parent. Brilliant!" [34, p. 40].

The dedicated *Midnight Resistance* coin-op cabinet uses a rotary joystick for each player, moving it in eight directions controls the characters movement, while rotating the stick fires the weapon through in a





(a) Arcade.



(b) Amiga.



(c) Commodore 64.



(d) ZX Spectrum.

Figure 19: *Midnight Resistance* platform comparisons.

circular arc. For example, the character can run forwards while shooting in an 360 degree rotating pattern. Just as with *Rainbow Islands*, the home version of *Midnight Resistance* simplifies the control scheme to work with a single button, eight direction joystick. To rotate the angle of fire the player must hold down fire and rotate, individual gunshots at a rapid fire pace to not affect the direction of movement. The one button control scheme is successful in translating the rotating fire gameplay mechanic to the home systems.

#### 5.3.6 Conversion Augmentations

The home microcomputer versions of Toaplan's *Snow Bros* for the Commodore Amiga and Atari ST by Ocean Software France (1991) never saw a commercial release due to licensing difficulties [9]. Following the trend established by the earlier arcade conversion workflows at Ocean for *Operation Wolf* and *Midnight Resistance*, Toaplan supplied the team with the coin-op original, who in turn performed an observation-based transferral of the game assets and logic by directly referencing the arcade screen.

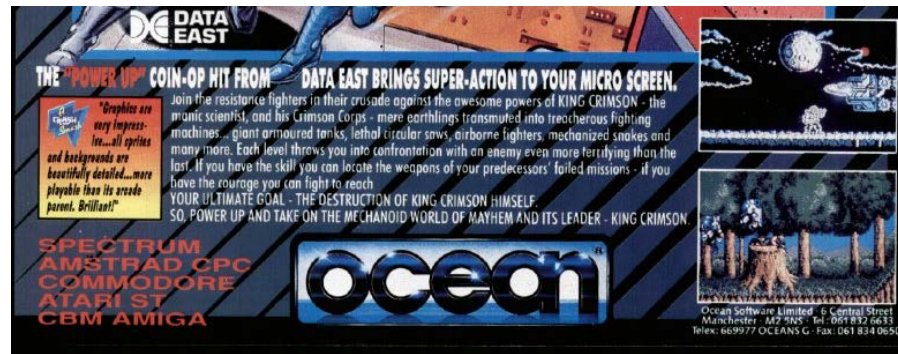


Figure 20: Ocean Software's *Midnight Resistance* magazine advertisement, prominently features the ZX Spectrum conversion (top right).

The developers used a combination of custom tools on the Amiga and Atari ST to perform the 16-bit conversions, allowing optimisation of memory and storage resources:

“specially written software which allowed them to animate the sprites within a very small amount of memory and also compact the screens. With the memory saved by these special techniques, the actual coding was made easier, and Pierre was allowed a pretty much free reign to incorporate nigh-on everything from the coin-op” [9, p. 28].

When compared to the assets from the arcade version, the sprite sheets closely resemble the original, but have slight idiosyncrasies, bearing the artistic flair of the conversion artist. *Snow Bros* on the Amiga also features the addition of an original animated introduction that adds an extra narrative layer to the original game scenario (Figure 21).

The 16-bit ST and Amiga ports of Capcom's *Mercs* by Tiertex (U.S. Gold, 1991) was also carried out using just the arcade machine as reference, with developers Anthony Ball and David Bland adding their own modification to the original in the form of a clown nose weapon (Figure 22) which while humorous was completely out of step with the tone of the game [178, p. 166]. A game tester spotted the rogue clown themed weapon and requested its removal. In response Ball and Bland added a hidden level to the Amiga version called the Secret Garden, which contained the banned Clown Nose weapon, so undoing the hidden weapon ban. The *Mercs* programmers also rebelled against Tiertex company policy by hiding their names on the credits page, their details made accessible by pressing the star key on the numeric pad.



Figure 21: The Amiga and Atari ST exclusive *Snow Bros* intro animation.

#### 5.4 CONCLUSIONS

The arcade to home microcomputer ports detailed in this chapter demonstrate that while often the original arcade developers supplied source graphics on disk, in addition to paper-based design documents and music notation, the conversion teams relied overwhelmingly on the original arcade machine as a reference when working on all areas including gameplay, audio, and visual aesthetics.

There are a number of factors that can be attributed to this ‘go it alone’ methodology employed by the conversion teams. In part it can be connected in part to the communicative and geographic disjoint between the original arcade developers located in Japan and the conversion teams situated in Europe. Without the benefit of Internet-based instant communications and translations, and reliance on the transfer of digital media through the postal service, this difficulty in exchanging digital assets and design insights between both sides made it necessary for the conversion teams to be self reliant in their production process.

An example of the platform divide between the eastern and western markets of the late 1980s and early 1990s is the Sharp X68000 (1987). An early multimedia powerhouse, the X68000 was used as the development machine for Capcom’s CPS1 arcade titles, includ-



Figure 22: The Amiga rendition of *Mercs*, featuring the secret Clown's Nose weapon.

ing *Street Fighter II: Champion Edition* (1993) and *Final Fight* (1992). Both of these arcade titles were published as near identical ports for the X68000 in the Japanese home market, albeit with the inclusion of floppy disk-based storage and loading times. This platform had a unique operating system and was not part of the western home computer ecosystem, providing an obstacle towards direct home conversions. Apart from the technical parity of the X68000 and CPS1 platforms, the X68000 versions of *SF2:CE* and *Final Fight* were produced in-house by Capcom, a far cry from the technical, logistical, and communicative distance experience by U.S. Gold's arcade to home conversion developers.

Another critical factor were the crunch time schedules that the conversion teams operated under, for example the 4 month deadline in which the five different *Forgotten Worlds* home adaptations were produced by a team of 6 people. Considering this time constraint it is understandable that the teams forged ahead on an independent and focussed development schedule.

In all the instances discussed, even when original graphics files were made available, the original arcade machine was played, sketched from, recorded, and in one case hardware hacked through the addition of a pause button. Nonetheless the code and audiovisual assets contained within the reference PCB remained inaccessible as a closed off, black box platform.

From the examples covered, none of the conversion teams were supplied with source code from the original arcade versions, necessitating writing all code from the ground up. The commercial PDS system used by Arc Developments streamlined the development pro-

cess allowing for use a central PC compatible system for machine code programming, which was then transferred to each of the target platforms. Each development team also used custom toolsets to build their products, for example to convert between graphics file formats, to enable porting content between each platform where appropriate. The Atari ST to Amiga workflow of Graftgold's *Rainbow Islands* 16-bit conversions constitutes a port within the process of creating arcade conversions, with the baseline system taking dominance in the development cycle.

Apart from the most immediate platform constraints of visual resolution and audio playback capabilities, data storage, memory, and processing constraints also shaped the gameplay experience. The addition of load times between levels, and the subtraction of non-essential features such as extra animation frames, and layers of parallax scrolling on the backgrounds were necessary in order to preserve the core gameplay experience.

Cassette and floppy disk storage media can impose significant loading durations, often drastically altering the pace of the arcade experience. The 1992 conversion of Capcom's *Street Fighter II* by U.S. Gold for the ZX Spectrum (Figure 23) is an extreme example. The long and repeated loading times add an extra layer layer of tension to the game, testing the player's patience through a meta game where the gamer must carefully rewind or fast forward the cassette tape to the correct counter location in order to successfully load the next stage.



Figure 23: The ZX Spectrum cassette loader version of *Street Fighter II*.

The ZX Spectrum home conversion of Data East's *Midnight Resistance* demonstrates that a port to a less technically advanced platform can result in an experience that is faithful to the original and extends it into a new direction. By exercising artistic license and understanding how to expressively harness the aesthetic constraints of the target platform alongside an adeptly adapted control scheme, the original gameplay feel can remain and compensate for a lack of pixel perfect



### visual accuracy

Similarly the easter eggs added by the *Mercs* conversion team and the extra cutscene graphics included in the Amiga version of *Snow Bros* demonstrate the room for creativity by expansion of the game-play flow and narrative by the conversion teams. Even where no extra features are added to the game, the analog filter of human machine art interface leaves subtle and indelible imprints of the team's own individual process aesthetic on each home port, illustrating that the arcade to home computer ports of the late 1980s and early 1990s often went beyond duplication, becoming adaptations carrying the unique creative signatures of their translators.

### Part III

## ARCADE SELF-REFLEXIVITY





## ARTEFACT A: CONTROL

---

*Control* is an experimental prototype art game that embodies the resolution divide between the real and virtual worlds, as mediated through the arcade videogame interface.

It is a self reflexive artefact, a meta game that provides a critical articulation of interface constraints by using the arcade videogame interface to explore its own limitations. These limitations in terms of both the control scheme and the audiovisual aesthetics serve to illustrate the distance in the communicative link between the digital and non-digital.

*Control's* narrative presents a timeline of controller complexity. This serves not only as a historical reference, but also as a robust challenge for players interfacing through the games deliberately constrained control scheme. The journey through game controller evolution combined with the high difficulty level encourages increased awareness of and empathy towards the role of accessibility in videogame design.

This chapter is divided into three broad sections:

1. [Background context.](#)
2. [Materials and process.](#)
3. [Dissemination, reaction, and evaluation.](#)

### 6.1 BACKGROUND CONTEXT

For most games and interaction design pieces, the aim is to make the user forget that they are connecting to the computer through an interface. In the bid for greatest accessibility, most often with the ulterior goal of maximised sales, the interface link is abstracted to become seamless and invisible.

In *Control* however, the interface link actually becomes the game, mirrored back to the user by the visual interface through a low bitrate representation of their hand on a physical controller. This chapter section details the background contexts that shaped its design and implementation.

### 6.1.1 *Physical Constraints in Arcade Gaming*

The physical control aspect of the human-computer interface in gaming typically is associated with the computer joystick, or gamepad controller. Iconic examples of both of these modes of control are the Atari 2600 joystick (1976), and the Nintendo NES joypad controller (1985). The computer keyboard also serves as a common game control device, in particular for systems that historically did not include a joystick port as standard, such as IBM PC compatible. The arrow keys or the combination of W, A, S, and D are common control schemes for directional movement when using the keyboard as a game controller. From the first arcade joystick with a fire button in Sega's 1969 *Missile* [135, p. 58], the functionality of the joystick input device has continued to evolve. This continued development is in response to the control schemes demanded by increasingly complex gameplay experiences, and enabled by technical leaps in software and hardware engineering.

*Space Invaders* (1976) used a joystick with two-way movement to move the player's ship on the x-axis. *Pac-Man* (1980) features a maze where the player moves in four directions along the x and y axes, and the joystick functionality physically conforms to this 'up, down, left, right' control scheme. The standard eight direction model remains the staple design for most modern arcade joysticks such as the Sanwa brand, allowing both four way and eight way directional functionality. Four way mode is imposed through a constraint bracket. This artificially enforced physical constraint affects gameplay. In the case of *Pac-Man* it removes the possibility of wasted player exertion on a diagonal directional move that will not be registered by the software.

### 6.1.2 *Game Controller Categories*

Physical game control devices fall into two categories, specialised and general. Specialised physical controllers are designed for one game in particular, for example, the bespoke guitar style controllers used in *Guitar Hero* (2005). An example of a general game controller is the Xbox 360 control pad (2005). This device must be adaptable for a variety of different gameplay experiences, and so includes a wide number of input controls. Alongside front and shoulder mounted action buttons and a standard directional pad, the Xbox 360 controller includes dual analog control pads, in addition to vibrating force feedback that is triggered by in-game events.

If we compare the Xbox 360 joypad with the Atari 2600 joystick (1976), we can see that over the last three decades, the level of physical

interface complexity faced by videogamers has increased significantly. The game controller timeline charted by Nicholas Nova [135, pp. 98-99] offers a visual reference to the evolution of game controllers, illustrating the leaps taken in ergonomic and technical sophistication in the videogame controller over three decades, and back further to the invention of the haptic pilot joystick and radio control toy controls.

The affordances offered by more complex controllers have led to new developments in game design. For example, the N64 joypad was designed specifically to allow the movement of the camera in 3D environments. "Nintendo went even further by dedicating four buttons on their N64 joypad to controlling the view of the action. While playing Nintendo game such as Super Mario 64 (Nintendo, 1996) the user can continuously adjust the position of the camera" [116, p. 91].

### 6.1.3 *Affordances and Constraints in Gaming*

The balance between constraints and affordances in videogame design is a delicate one. An affordance is a usage scenario that is communicated by the game system, for example, a trigger button affords firing. A constraint is a limitation placed on this usage, an example of a constraint is a time limit placed on a gameplay session.

Without a challenge, there is no game. For example, the one button game as illustrated by Juul [89, p. 12]. In this scenario, the player must only click one button to complete the game. It is not the single switch that leads to lack of challenge in this case, but the near non-existent gameplay mechanic that accompanies it. There is no balance between challenge and control in this case. The ease of use must be offset by the prospect of a learning curve. "For something to be a good game, and a game at all, we expect resistance and the possibility of failure" [89, p. 12].

### 6.1.4 *The Controller as Game Focus*

The *Shooting Watch* (Figure 24) by Hudson Soft takes the tactile button pressing experience of the gamepad and removes the device's dependence on a connected videogame system. It is a self contained unit, providing reflex and timing challenges through a simple numeric LCD visual display and a basic timer-based circuit. Takahashi-Meijin is synonymous with the shooting watch, and was famous in Japan in the 1980s for his ability to hit 16 shots per second [98].



Figure 24: Hudson Soft *Shooting Watch*.

#### 6.1.5 Control Schemes as Constraints

*Control* schemes map how user interactions are transposed onto a user interface. In the context of arcade videogaming these communications typically take the form of hand operated manipulations of the physical control panel. For example; the basic arcade control setup of a joystick alongside one or more action buttons.

It is possible to take the single switch control mechanic and map it to a complex gameplay experience. This approach is highlighted at [Oneswitch.org.uk](https://Oneswitch.org.uk), an online resource that raises awareness of accessibility needs in video gaming. The website advocates the modification of existing games for usage with simplified control schemes, as well as providing information on how to adapt videogame controllers, increasing their physical accessibility.

"Video games are fun and also give people the power to do amazing things that they would be unable to in real life. With the right specialised hardware, many standard video games can be played by anyone, no matter the disability" [53].

<sup>9</sup> The term *schmup* refers to horizontally or vertically scrolling 2D shoot-em-up games.

The touring Argentinian indie schmup<sup>9</sup>, *NAVE* presents a fundamentally simple control side interface through its one switch alongside an eight direction joystick (Figure 25) . Even if a new *NAVE* player were unfamiliar with the convention of the directional joystick or the singular functionality implied by a digital fire button, the link between form and function is easily understood by the user. By offering visual and audio feedback in tandem to player movements, *NAVE* communicates the relationship between player movements and their actions in diegetic space clearly and concisely. Its reductionist nature significantly reduces error margins and fosters intuitiveness.

Arcade control panels range from generalised configurations designed to house multiple titles to bespoke solutions engineered for a single game, often with custom peripherals designed to increase



Figure 25: NAVE control panel in use.

immersion, such as light guns and steering wheels. While an arcade software title's control scheme is intended to stay static across multiple cabinet install setups, their input mapping is also affected by the wiring of the *JAMMA* harness [37, p. 476] and whether or not this conforms to the intended control scheme set out by the manufacturer (Figure 26). This means the physicality of an individual cabinet install by the arcade operator can affect the originally intended interface link designed by the game development team.

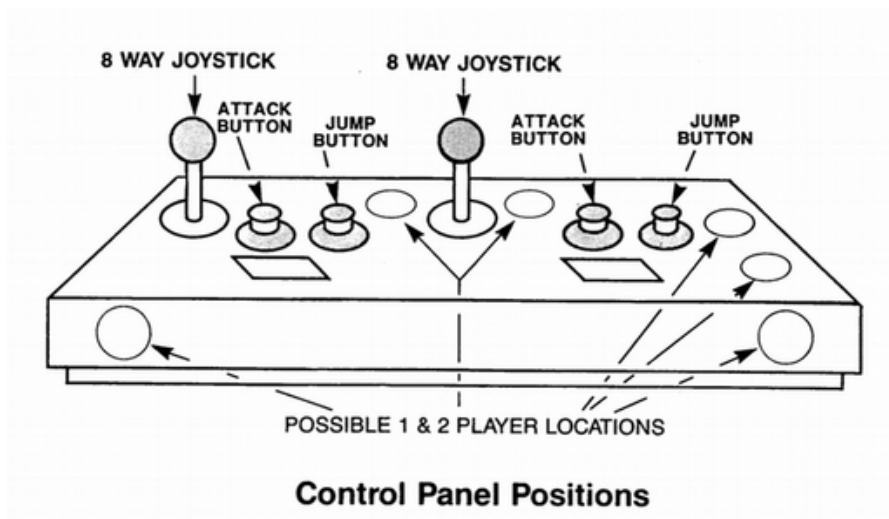


Figure 26: Control panel layout from the installation documents for *Final Fight* (1989).

Similarly when arcade control schemes are transposed from the arcade to home computer and console system translations through ports or emulation, the button mapping and overall graspability of the physical interface link can differ from the original implementation. The extent of this variance is affected by the affordances and constraints of the platform's control surface, in addition to design decisions made during the software authoring process.

The Sega Naomi arcade system is an interesting missing link of sorts between arcade control panels and home console controllers. The control panel for the Naomi build arcade cabinet has a controller port designed to accommodate the Sega Dreamcast home console controllers (Figure 27). This design decision was made based on the hardware similarities between both platforms and also as a move to prop up sales of the Dreamcast console while retaining arcade customers.



Figure 27: Sega Dreamcast enabled control panel.

In redesigning an arcade born title for a home platform the designers must consider the largest audience possible, in other words the user base with a baseline system configuration devoid of any specialised control peripherals. Each home computer or videogame console system has a default controller, whether that is the keyboard, mouse, or a gaming specific peripheral such as a joystick or gamepad.

Controller button counts have evolved over the years in response to increased technical capabilities in videogaming that have enabled more complex gameplay, demanding intricate control functionality where necessary. This increase in functionality has raised the bar for novice gamers and those who may find the manual dexterity required beyond their abilities. The *Control* art-game critically highlights the issue of game interface complexity by taking the player on a journey where they must interface with an increasingly complex series of controllers, while constraining the full movement of their onscreen hand within the control scheme of a single set of directional controls and one action button.



### 6.1.6 Porting Arcade Control Schemes across Platforms

*Street Fighter II* (1989) revitalised the arcade industry in the early 1990s, leading to many clones and the firm establishment of the fighting game genre [105, chap. 3]. Its combo-based gameplay pushed the standard for arcade buttons from four to six, achieved through a custom wiring augmentation called the kick harness that wired the two extra buttons direct to the PCB. *Street Fighter II* (SF2) was largely distributed in the form of conversion kits that contained the game PCB alongside cabinet signage and instructions on how to convert a regular cabinet to SF2 configuration. This reconfiguration of existing arcade cabinets demanded a considerable effort in terms of DIY endeavour, requiring the arcade operator to fabricate a new control panel according to the template supplied in the manual, alongside additional woodwork and electronic skills.

The six button control scheme is intrinsic to the *Street Fighter* series gameplay. Throughout the years SF2 and its sequels have been ported across multiple non-arcade bases systems, with many of the ports providing interesting workarounds to the control constraints posed by the host platforms.

Home console controllers were also augmented to support the SF2 control scheme, and where necessary, concessions were made to support non-custom controls. The launch version of the Super Nintendo / Super Famicom console joypad was designed with 6 action buttons specifically to accommodate SF2, leading to the introduction of the joypad shoulder button. Playing *Street Fighter II* on the Super Nintendo joypad or any non-arcade standard controller for a player accustomed to the original arcade interface requires a certain amount of initial unlearning and cognitive adjustment, similar to a guitarist adjusting their play from a classic guitar to flying-v. Both instruments perform the same task, but their form factor directly affects how they are held and subsequently bear on the resulting style of play.

*Street Fighter II: Championship Edition* for the NEC PC Engine console (1993) suffered from the limits of the PC Engine's standard two button gamepad, meaning that the six button gameplay had to be accommodated by using the start button as a third in-game play button, and the select button to toggle between the three levels of punch or three kick levels. A special six button joypad was designed especially to accommodate *Street Fighter II:CE* on the PC Engine, as was also the case for the Sega Mega Drive / Genesis port which expanded beyond the systems previous 3 button standard.

*Street Fighter IV*'s mobile touchscreen ports attempt to replicate the arcade and joystick button convention through a partially transparent representation superimposed over gameplay [136, p. 121]. While the fingertips to glass contact lacks the tactile feedback of authentic physical controls, the virtual control layout approximates the original experience sufficiently to allow unobstructed immersion. This constant finger tapping and momentary sliding of the digits on glass reinforces the touchscreen interface as a window into the diegetic game space, a boundary point, but also a transmission zone where communication is exchanged two ways yet it cannot be crossed by either side.

#### 6.1.7 Joysticks to Joypads

The evolution and emergence of joypads as a domestic analog to the standard arcade control panel was influenced by multiple factors, including usability, ergonomics, patent circumvention, business politics, and manufacturing budgets.

The Atari VCS was at the forefront of the initial wave of home gaming systems that used arcade joysticks and paddles, directly transposing a familiar interface convention to the home consumer space. This straightforward approach matched the expectations of customers seeking an authentic arcade experience.

However, it paid little consideration for the ergonomic and environmental differences between playing games on coin-operated arcade machines. Arcade coin-ops are self-contained and typically played at close proximity to the screen. By contrast, television connected home gaming systems are usually played while seated, and when the VCS was originally released they were normally operated at distance from their visual display via a tethered controller [135, p. 47].

The now ubiquitous interface convention of the directional pad originates from Nintendo's Game and Watch platform, a series of handheld electronic games developed using LCD calculator technology designed for discrete play on public transport. When Nintendo were developing the Famicom console they invented the first console joypad by adapting the Game and Watch crosspad as a videogame controller.

Similar to how the Atari VCS was engineered to allow the play of *Pong* clones at home, the Famicom was developed so that Nintendo could bring their arcade titles to the home space without reliance on outside hardware vendors. The baseline Famicom specifications were influenced heavily by the *Donkey Kong* arcade machine, but also de-



signed to be three years ahead of the competition at launch. Famicom joypads maintained a standard arcade interface convention by placing the directional controls on the left. Gunpei Yokoi saw this as a moderately risky decision since most people are right handed, but recognised that swapping the directional pad to the right would have altered the natural mapping for millions of *Donkey Kong* players [67, p. 38]. Nova and Bolli refer to this mental mapping of the control terrain as ‘path dependency’ [135, p.90].

Just like the Game and Watch, the Famicom controller was easy to hold with two hands while simultaneously allowing access to its control surface by both thumbs. The crosspad’s minimal build was considerably durable in comparison to home console joysticks, and proved economic in terms of cost. Also, the Famicom controllers were easily stored on the sides of the console allowing for easy storage, proving advantageous for the Japanese market where living space is at a premium. Since Nintendo already held the crosspad patent, they were not reliant on licensing existing joystick patents.

Despite the exclusivity of the crosspad design, the directional pad concept was soon approximated by competitors. The first rival console to use a joystick was Sega’s Mark 2 system, a direct competitor to the Famicom. Instead of a control pad it used a flat, square shaped directional controller, with the cross configuration raised on it’s surface. It’s notable that while Sega invented the joystick [135, p. 58], they didn’t attempt to deviate from Nintendo’s gamepad innovation, instead flattering them through imitation.

Atari used a similar patent circumventing approach with a circle-shaped direction pad, a trend popularly continued in joystick design by the videogames industry at large including NEC, Atari, and Fujitsu. An alternative reverse engineered approach was taken for Sony PlayStation and Commodore CDTV controllers, both use four separate buttons placed closely together in a d-pad configuration.

*Control* echoes the nascent first steps taken in adapting arcade control systems to consumer space in its first level based on the Atari VCS controller. Levels two to ten present a potted history of gamepad evolution, reflecting their increasing complexity as a result of increased technical affordances, while critiquing their ever increasing complexity.

## 6.2 PROCESS AND MATERIALS

The design of *Control*'s levels, graphics style, and gameplay occurred in parallel to each other, with the affordances and constraints relating to technical, aesthetic, and gameplay choices each interplaying off each other as development progressed.

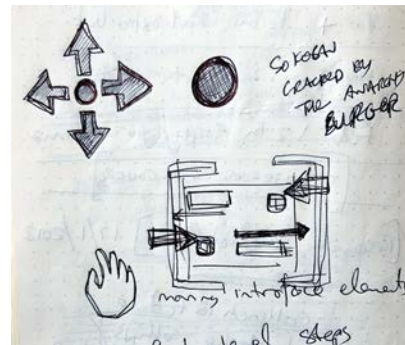
The aesthetic style settled upon for *Control* was a sprite-based, 2d approach inspired by home arcade conversions during the early 1990s. All the game graphics are unsmoothed and aliased to emphasise the palette limitations. The constrained aesthetic is framed within the narrative of a fictitious home computing platform inspired by the limited colour palette of early MS DOS games running on IBM PC compatibles, and the tape loader raster bars of the Commodore 64 and Sinclair ZX Spectrum.

### 6.2.1 Initial Concepts

*Control* was originally titled *Game About Game Interfaces / GAGI* (Figure 28a). Initial concepts were explored on paper (Figure 28b), before moving to digital mockups, through a series of sketches visualising possible gameplay scenarios and outcomes involving the game interface as the sole focus of diegetic gameplay.



(a) Game About Game Interfaces.



(b) Interface game concept sketch.

Figure 28: Early *Control* concept sketches.

Among the numerous gameplay scenarios explored was one where anthropomorphic game controllers (Figure 29) appear as game opponents that demand clicking to disarm them, a non-violent homage to Taito's *Operation Wolf*. Another concept involved a level journey themed around infinite regression through video monitors of varying graphics standards.

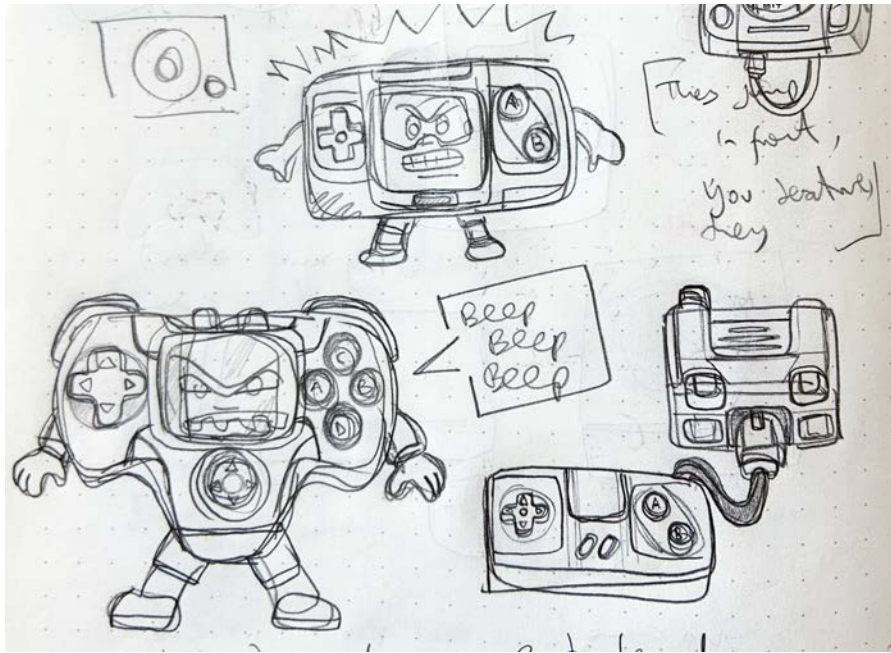


Figure 29: Anthropomorphic controllers as game characters.

### 6.3 AUTHORIZING ENVIRONMENT

The game was authored using Stencyl, chosen for its ease of use as an environment for the rapid prototyping of 2d games, and for its support of Windows, OSX, and Linux as publishing platforms. Stencyl was also chosen since its tile-based graphics system approximate the constraints encountered by 2D arcade game developers in the 1980s and 1990s (Figure 30).

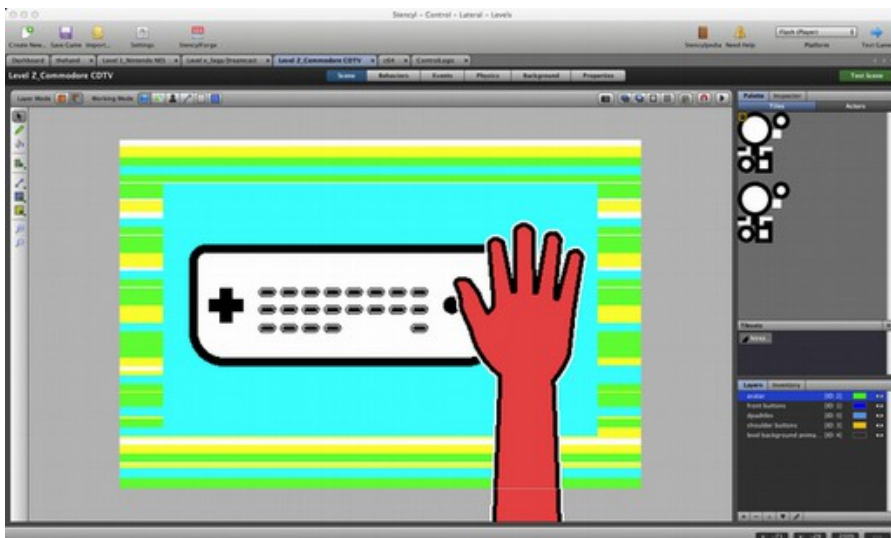


Figure 30: Stencyl authoring environment.

While the game was designed with desktop platforms in mind, it was considered that the game may be ported to smaller mobile resolutions at a future date. The base resolution was set to 480 x 320, with the graphics drawn at 4x resolution. Allowing a max resolution of 1920 x 1280, with hardware scaling interpolating for screen sizes under this. As such, all graphics were drawn so that they could comfortably display at 1x, so for example, the black outline used for the controller body tileset is eight pixels wide, and at its smallest resolution displays at two pixels wide.

The bulk of *Control*'s software build took place between mid-June and early September 2013. Stencyl 3.0 was in beta development during this period, as a result there were times where it was unclear if errors or bugs in the application were due to bugs in the authoring application or human error. This situation required required constant engagement with the Stencyl community forums and resources, and the adjustment of code to accommodate the affordances of each new Stencyl 3.0 beta build (Figure 31).

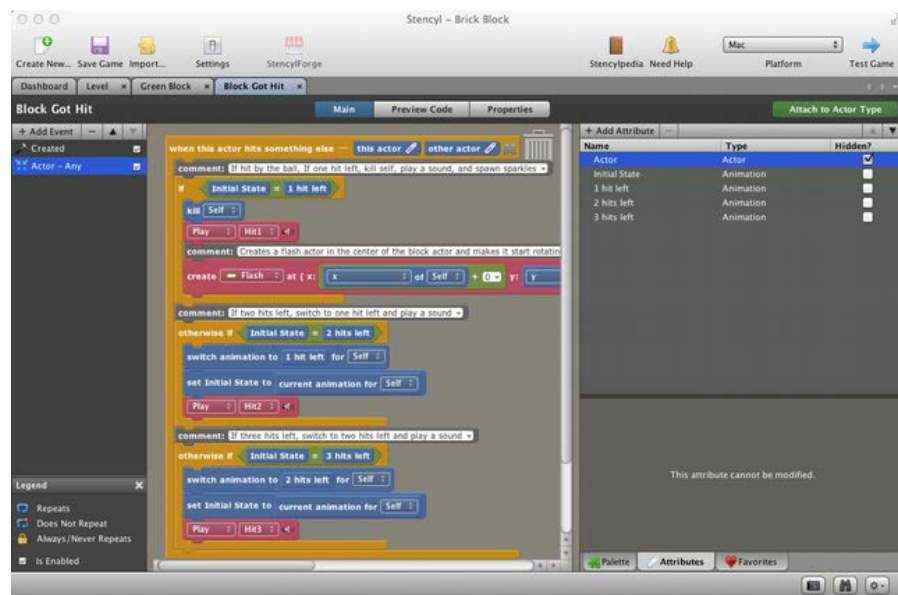


Figure 31: Code blocks in the Stencyl authoring environment.

### 6.3.1 Visual and Sonic Palette Constraints

*Control*'s visual style is a hybrid of early PC gaming graphics, borrowing hues from the four colour CGA adaptor used in early IBM PC compatible machines, combining them into the EXCGA palette and resulting in a neon tinged aesthetic. This new palette channels the aura of the original graphics hardware it is based upon, while

displaying at a higher resolution.

This reference to early PC gaming is merged with the tape loader aesthetic of 8-bit computers such as the Commodore 64 (1982) and Sinclair ZX Spectrum (1982). Animated loading bars are traditionally associated with the anticipation of game loading, but in this case are reappropriated as feedback indicators, changing colour in response to the player's progress. There are five variations of the background loading animation. Four of these correspond to the player's energy level during gameplay, with a fifth animation that plays when the player loses all their energy.

Pixen and Photoshop were used as the graphics production platforms, with the majority of work done through Pixen, which is purpose designed for aliased, tile and sprite graphics production. Colour cycling animations are used to compensate for the limitations of the chosen colour scheme, a technique commonly used on vintage videogame systems. This technique proves effective as a feedback method when used to visually highlight in-game target areas.

### 6.3.2 *Soundtrack and Audio Effects*

The music for *Control* was composed using *Little Sound Dj / LSDj* which runs on the 1989 Nintendo Game Boy. *LSDj* allows access to the Game Boy's 4 channel sound chip via a tracker-based interface. It was chosen as an era-appropriate sound aesthetic, producing a chip-tune sound immediately identifiable with 8-bit videogaming.

The in-game level theme uses a simple 4 bar, 72 beats per minute loop. There are four variations of the game theme that play in response to the player's energy level, at 100%, 75%, 50%, and 25% respectively. As the player loses energy, the themes become more frantic, so increasing the sense of urgency.

Gameplay errors are highlighted with a sampled sound taken from the tape loading sequence for the ZX Spectrum conversion of *Chase HQ* running through the emulator Fuse. Similar to the noise made by a fax machine upon connection, it provides a shrill auditory jolt before progressing to the next stage of gameplay. The open source audio editing application Audacity was used for recording, editing, and sound file conversion and export.

### 6.3.3 The Assembly and Build Process

Various gamepads and joysticks were drawn at different perspectives and considered for inclusion as game levels (Figure 32a). Initial versions of the grid and tile-based approach to build the in-game graphics were also sketched out on paper (Figure 32b) and rendered digitally (Figure 33). A top down rather than sloped or isometric view was decided upon for design efficiency and visual clarity. The z-axis position of the player hand stays static throughout the game. For the majority of the levels, buttons and short analog thumbsticks are depicted, meaning that the relatively short height difference between both input devices could use the same hand animation.

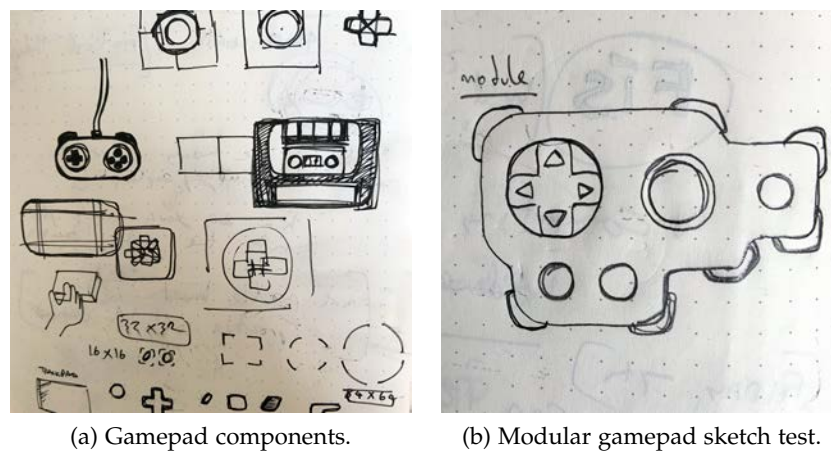


Figure 32: Gamepad concept sketches.

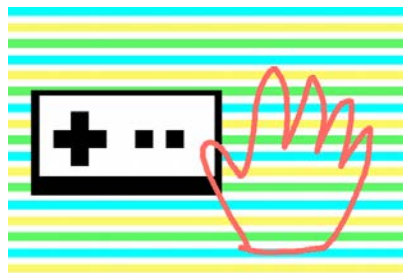


Figure 33: Early graphic concept testing an angled joypad view and outlined hand.

Some artistic license was taken for levels one and seven, the Atari VCS / 2600 and Atari 5200 respectively. Each joystick is depicted using the stubby analog stick graphics used elsewhere instead of a regular height joystick. The inclusion of the Atari 2600 was necessary as fitting with the narrative of the VCS as an evolutionary link between the arcade space and home arcade gaming via joypads. The minimal graphics and brevity of the level mean that this inconsistency does



not draw unnecessary focus from the in-game task at hand. Also by the time a player has reached level seven, defeating the level is their main priority rather than the x-height of the joystick.

After a preliminary version of the tileset was designed (Figure 34a), the components were collated together into a single sprite sheet and imported into Stencyl (Figure 34b) where a non-playable prototype of one level was developed to demonstrate the look and feel of the game as a visual proof of concept (Figure 35a).

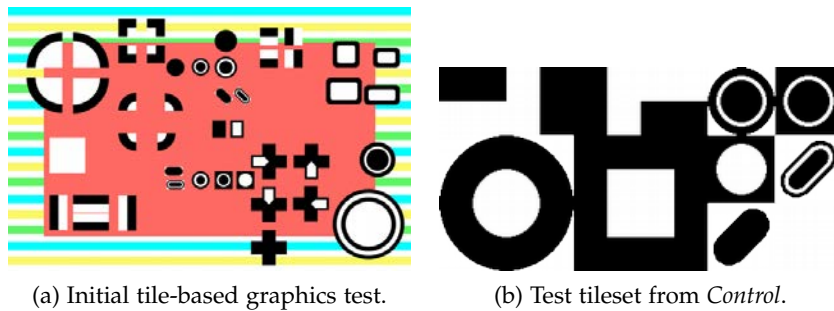


Figure 34: *Control* tileset graphics tests.

Each of the game onscreen controllers was built using a series of predefined graphic tiles. The tileset evolved along with the development of the levels as decisions were made on which controller designs best translated to the resolution constraints of the grid (Figure 35a). For example, the PlayStation Dualshock controller design underwent several iterations before it was finalised, in order to keep the design recognisable yet minimal, and to maintain consistency with the other levels. This modular approach enabled the creation of multiple controller configurations from a limited number of graphical assets.

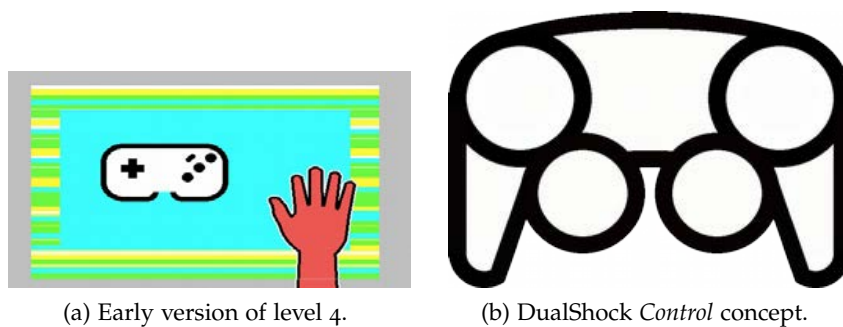
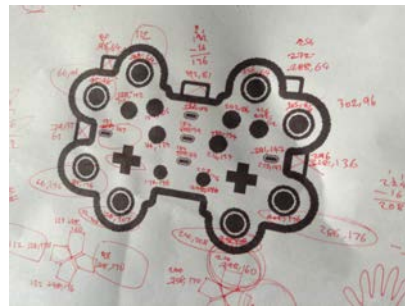


Figure 35: Early controller graphics tests.

The approach taken was to use background tiles to build the shapes of each controller, with interactive character sprite graphics used for the buttons. This aligns with the techniques used to animate over-

sized non-player objects (normally end of level boss characters) on platforms with limited processing ability such as the NES, where background graphics are used as the body of the object, for example or a vehicle or alien, and the vulnerable hit points are player sprites. The stylised monochrome graphical elements meant that the controller building blocks are generic enough for use across multiple platform brands without overly identifying with one gaming company or another.

The interactive elements were first manually placed on the grid, then a screengrab was printed and their coordinates noted down (Figure 36a). The position for each clickable element was then entered in the code. This allowed for each piece to be spawned (replaced) appropriately in reaction to collision with the active fingertips (Figure 37b).

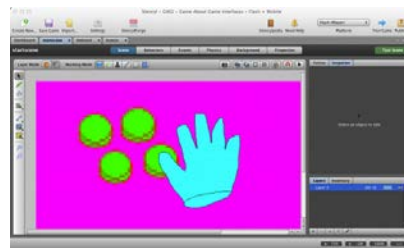


(a) OctoPad development document.

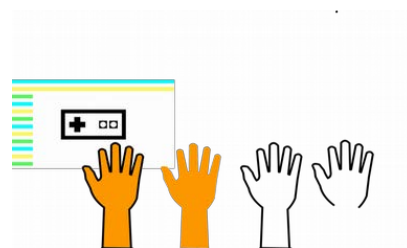


(b) The OctoPad onscreen.

Figure 36: *Control*'s OctoPad development and implementation.



(a) Early *Control* interaction test.



(b) *Control* hand development graphics.

Figure 37: *Control* hand concepts.

Once the functionality of *Control*'s hand to button interaction was programmed, the placeholder graphics (Figure 37a) were replaced with the controller test levels and a hand graphics consistent with the overall aesthetic (Figure 37).

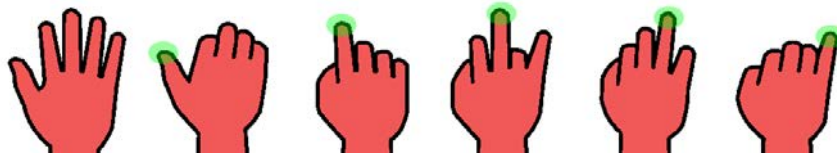
Figure 38 details the final versions of the onscreen hand. The green highlight is used here to illustrate the collision area, but is not visible



NAME	LEVEL	BUTTONS	CLICKS	TIME
<i>Atari VCS / 2600 - CX40</i>	1	2	12	20
<i>Sega Mk2</i>	2	6	12	50
<i>Famicom / NES</i>	3	8	20	60
<i>MD/Genesis - SJ-3500</i>	4	8	28	70
<i>3D Pad - MK-80117</i>	5	13	30	100
<i>Dualshock SCPH-1200</i>	6	14	42	120
<i>Atari 5200 - CX52</i>	7	18	40	130
<i>Jaguar - J8901</i>	8	21	56	150
<i>Commodore CDTV</i>	9	28	52	200
<i>OctoPad Prototype</i>	10	34	60	180

Table 3: *Control* level summary

in-game. From left to right: hand with no finger selected, left + fire, left + up + fire, up + fire, up + right + fire, right + fire.

Figure 38: *Control* hand collisions test.

#### 6.3.4 Control Description

The goal of *Control* is to successfully click all the interface elements that are highlighted on each level within the set time limit, while negotiating the limitations of the game's own manual control scheme. It is expected that the player will encounter failure and frustration during gameplay, as with any challenging game.

*Control* has 10 levels (Table 3). The first 9 of these are based on existing videogame controllers, while Level 10 is the 'OctoPad', an experimental concept prototype. The player must successfully press all the highlighted controls to proceed to the next stage. If the timer or energy level reaches zero then it's 'Game Over'!

The player is represented onscreen by a hand avatar, which is controlled using the basic arcade videogame control mechanism of 8 directions and one action button. The five digits of the hand are individually used to press the onscreen game controls. In order to use one of the fingers, the player must hold down the action button along with the appropriate directional controls. For example, the combination of left and action corresponds to the thumb.

*Control*'s visual style is in part inspired by early PC gaming graphics, combining the colours from the different 4 colour CGA video modes into a new palette. This reference to early PC gaming is merged with the tape loader aesthetic of 8-bit computers such as the Commodore 64. Animated raster bars are commonly associated with the anticipation of game loading, but in this case are used as feedback indicators, changing colour in response to the player's progress. The audio is also kept within a deliberately lo-fi videogame audio aesthetic, combining samples of ZX Spectrum loading sounds alongside 4 channel loops generated on the Nintendo Game Boy.

The imposed nature of the control restrictions on the virtual hand, and their complexity in relative terms to their real world analogs, is intended to encourage increased awareness of the necessity for accessibility in videogame design, while highlighting the divide between the digital and physical worlds.

*Control* echoes the hand to controller aspect of the videogame interface in the diegetic space of the visual interface through a downsampled meta interface. It makes the game interface the constant point of focus, rather than have it disappear to make way for an unrelated feedback visual. This goes against the notion of the ideal of interface design where an interface should be so intuitive that it for all intents and purposes 'disappears'. In *Control* the visual interface will not let you forget that you're manually interfacing with the computer through a hand to controller link.

By using a low fidelity reproduction of the hand in the playfield, both visually and in terms of the available control scheme, the game reflects the resolution divide between the analog and digital worlds. In addition to the challenge provided, the increasing button count of the onscreen game controllers is intended to reflect the evolution of game input devices. The final level of *Control* confronts the user with the speculative 'OctoPad' prototype game controller that exaggerates the complexity of existing devices. The progress a player makes through the game levels is a measure of their own patience and ability to play within a constrained control scheme and increas-

ingly more difficult level layout.

In part *Control* also provides a commentary on accessibility in video gaming, and intends to reflect on the evolution and increasing complexity of game controllers, while concentrating the user on the physical and audio-visual constraints of human computer interfaces and how these relate to game design and game accessibility.

### 6.3.5 *Control Walkthrough*



(a) *Control* warning screen.



(b) Zencom PC startup screen.



(c) *Control* title screen.



(d) *Control* level 1 intro.

Figure 39: *Control* pre-gameplay screens.

*Control* (version 1.0) opens with a caution screen regarding its use of flashing images (Figure 39a). This was upgraded for version 1.1 with an additional message advising users to adjust their volume levels as necessary. The ZenCom PC boot screen merges of the visual aesthetics of early DOS-based PC displays, also taking influence from the Sinclair ZX Spectrum and Commodore 64 home microcomputers (Figure 39b).

After boot up *Control*'s title is displayed (Figure 39c), it is a trainer level where the player must literally get to grips with the game's control method. It contains text instructions on the goals of *Control*. The first in-game goal is to figure out the control scheme and successfully start the game. If there's no activity for 5 minutes the boot sequence replays. Each level of *Control* starts with a 'Get Ready' screen (Fig-

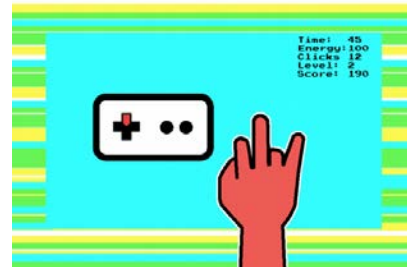
ure 39d). A colour cycling effect is used on the borders around the text to create the perception of an expanded palette.

The level sequence in *Control* reflects the evolution of game-controller complexity. It begins with the 1976 Atari VCS / 2600 joystick (Figure 40a), with eight directions and just one button. The time level on this level is extremely unforgiving. Level 2 features the Sega Mark 2 control pad (Figure 40b). Chronologically it followed the Famicom / NES pad, but is placed a level before Nintendo's pioneering gamepad (Figure 40c) because of its lower button count.

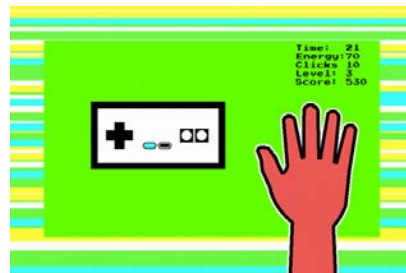
The fourth level makes the transition from the 8-bit to 16-bit console era with the Sega's 1988 Megadrive / Genesis controller in its original 3 action button configuration (Figure 40d). This controller was superseded by the 6 button in 1993 introduced to accommodate *Street Fighter II: Championship Edition*. Level 5 is the Sega Saturn 3D Control Pad, also known as the Multi Controller (Figure 41a).



(a) Level 1, Atari VCS 2600 joystick.



(b) Level 2, Sega Mark 2 control pad.



(c) Level 3, Famicom / NES gamepad.



(d) Level 4, Sega Megadrive joypad.

Figure 40: *Control* levels 1 to 4.

The design of the Sony PlayStation DualShock on level 5 was modified for maximum clarity while using the same shared tileset as the other game controller representations (Figure 41b). Level 7's Atari 5200 controller (Figure 41c) steps back chronologically to 1982 but increases in button count due to it's touchtone phone inspired keypad. It's followed by another Atari's much maligned Jaguar controller

(1993), also featuring a numeric keypad style button layout (Figure 41d).

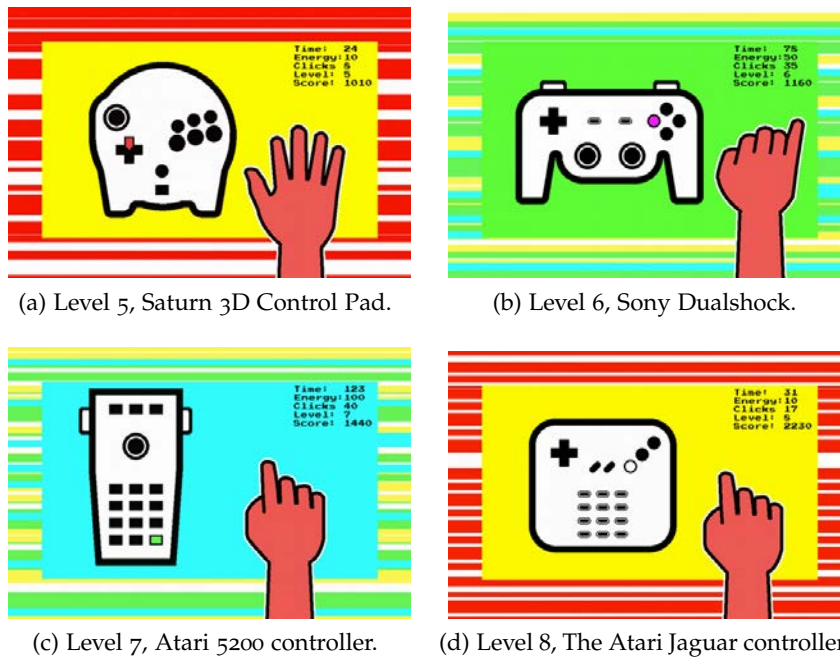


Figure 41: *Control* levels 5 to 8.

Level 9 ratchets up the difficulty level with Commodore's CDTV controller (Figure 42a), an infrared wireless device that merges the television remote control and gamepad conventions, with 28 buttons at the users disposal. *Control's* final level is the prototype OctoPad, a speculative prototype take on the future evolution of game controllers (Figure 42b). As a concept design it considers how game controllers may continue to develop in their increasing complexity if left to evolve organically.

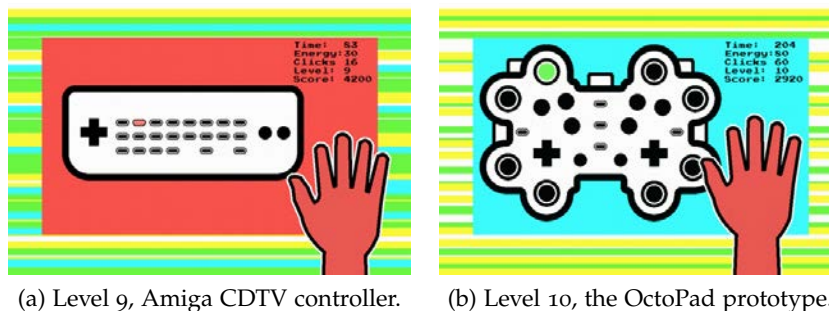


Figure 42: *Control* levels 9 and 10.

*Control* has two Game Over screens, one that is displayed when the time level runs out (Figure 43b), and another that signals that energy has reached zero. Completing a level overlays the play field with the

clear screen text banner (Figure 43a). When this animation appears the player can still move the onscreen hand and click the controller buttons, triggering visual and audio feedback, however this won't register points or damage. Upon successfully completing the game, the author congratulates the player for persevering through *Control*'s ten levels, while outlining the aims and context of the game as an experimental meta commentary on arcade videogame interface constraints.

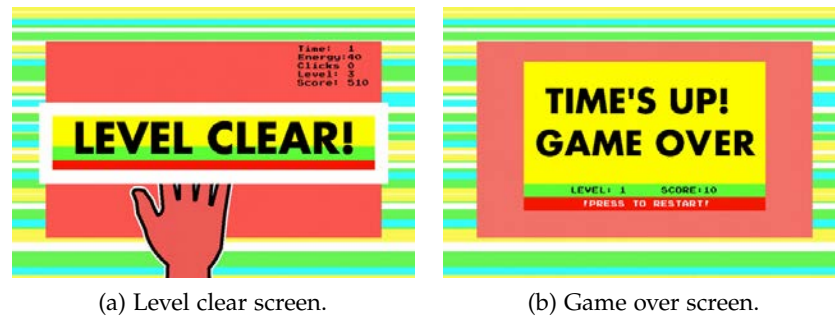


Figure 43: *Control* level clear and game over screens.



Figure 44: *Control* congratulations screen 1 of 4.

## 6.4 DISSEMINATION, REACTION, AND EVALUATION

The online reaction to *Control* version 1.1, alongside exhibition-based feedback to version 1.3 revealed three main themes that clearly align with the intended aims of the game. These were:

1. User frustration with the constraints of the interface.
2. The highlighting of game accessibility as relating to controller evolution.
3. The balance between the artefacts gameplay and artist concept.

Additionally, a number of additional salient points arose in feedback that provided pointers to how the experience could improve

and possible divergent paths it could take if upon further development. These findings are discussed and reflected on throughout this chapter section.

#### 6.4.1 *Pre-Release*

A webpage was set up at [kierannolan.com/control](http://kierannolan.com/control) acting as a central repository for all media relating to *Control* including press-release ready text, images, video, and external weblinks. This resource was linked to by media art source Creative Applications, and also by indie art-game blog The Metanoasis, who called *Control* ‘an intriguing experiment with familiar interfaces’ [186].

The inclusion of *Control* as part of the LA Game Space Experimental Game Pack 01 compilation leveraged a wide promotional push across social media in the months running up to the release date, reaching an audience interested in videogame design and digital art.

#### 6.4.2 *Online Launch and Indie Game Press Reception*

*Control* (version 1.1) was published by LA Game Space as part of the Experimental Game Pack 01 compilation on 12th September 2013. 12,980 copies of the game pack were preordered, with the launch gaining significant coverage in the indie game press. The Game Pack compilation featured 30 games by independent developers worldwide, and was released to funders of LA Game Space’s Kickstarter campaign.

Initial reviews in the online indie gaming press including Tiny Cartridge, Giant Bomb, and Indie Statik presented a mix of openness to the experimental premise and theme of the game, mixed with critical feedback its ease of playability.

On *Control*’s user frustration level, Giant Bomb and Indie Statik described the payoff between the limited control scheme and the abrasive audio feedback:

“The frustration caused by difficulty level alongside the abrasive glitch aesthetic of the audio feedback “Manipulating these controls without making errors (which is where the extremely loud noises come in, which sound like robotic cats getting mauled by cyberbears) and within the time limit gets harder and harder, because the player is also struggling with the game’s “hold two directions and space bar” type controls to get their fingers in the right place” [125].



"You have to press the buttons that are flashing; otherwise, you make a wrong move and cause the whole game to go into a meta glitch mode with excruciating digital sounds . . . Control is a pretty cool idea, and it's done fairly well, though I do wish it was easier to know exactly where you finger will press, but then, that is part of what makes the game hard as well" [144].

The accessibility issue too was identified:

"The game isn't so much honoring the evolution of video game control schemes than it is castigating it, demonstrating how difficult and confusing modern game controls have become for the simple layman to understand" [125].

Despite reservations concerning *Controls* playability, the concept proved interesting enough to offset the less pleasurable aspects of the game, at least to a point.

"It is an experiment, a concept, an interesting idea with a very high difficulty, and is very curious" (translation) [5].

This dichotomy is expressed succinctly by Giant Bomb:

"Control's both an intriguing exercise in meta-gaming and one of the least pleasant gaming experiences I've had certainly with this package of games, if not this year. These two aspects might not necessarily be unrelated" [125].

#### 6.4.3 *Gameplay Video Playthroughs as User Feedback*

Reviews of *Control* by gaming video bloggers began to appear on YouTube and Twitch within a week of the online launch. Gameplay videos provide honest, often visceral accounts of gameplay from a first person perspective. Even though *Control* was packaged with a readme.txt file, most of the reviews delved straight into the game, providing no-holds barred live commentary.

A perfectly designed interface should not warrant the use of a manual, however *Control* is purposely an imperfectly design interface and so prompted some ire among the reviews. For user-evaluation purposes, Let's Play videos align favourably with the thinking aloud method [133, pp. 6-7] used in HCI design as they contain spontaneous insights into the playing publics first impressions of the game. Twelve video walkthroughs were posted to YouTube over the course of the next two years.



#### 6.4.4 Video Review Findings

From the outset *Control* was designed with the use of a single button and directional control configuration. All mentions of button presses in-game refer to a non-specific switch, for example ‘press to continue’ (Figure 44) and ‘press to restart’ (Figure 43b). Since the player is interacting with a full keyboard, each key apart from the spacebar offers a redundant interaction possibility. Also when the game is displayed in windowed mode, the active nature of the mouse cursor offers an additional non-functional affordance that distracts from the minimal control scheme.

This was commented on by three of the YouTube reviewers:

“This is a game called Control, I’m going to press to continue press what, press to continue, I don’t know what I’m supposed to press, enter, spacebar?” [175].

“This is Control, it says press to continue, I’m not sure what, I still haven’t got by this screen, s—, it was space. I’m sorry” [141].

“Which is the action button? what are the controls, space? What, what am I supposed to be doing? I see, holding down space plus a direction does something what have I done? I don’t think I’m indie enough to appreciate this” [90].

Ideally if it were possible to detect if a game controller is connected and reflect this in code, then the text shown on screen could be adjusted to directly reference the appropriately connected game controller.

Splash screen number two revealed the next feedback point, one that had been overlooked during development, that of excessively high volume levels of the cassette loading audio in the intro sequence, as well the high volume of the error sound during gameplay. *Control* was developed on a system connected to external speakers, and it hadn’t been considered that many gamers use headphones.

“Woah! 10 feedback! That’s loud! Holy cow, that’s very loud” [175].

“before I get into the game proper . . . I suggest you turn down the volume on your media player, because once you hear it, its going to be ear wrenching, its going to make your ears bleed, I’m even have my headset off for this, thats how bad the noise is, when it happen, so without

further ado. Ow, oh! Even with my headset off it's still loud, oh man! . . . it's good, but it's noisy as hell when you hit the wrong button" [124].

"Oh god, ow!" [187].

In response to this feedback additional message was added to the caution splash screen shown on boot up of *Control*, advising users to adjust their volume levels as necessary. The volume of the loading screen noise was also reduced slightly.

The title screen doubles as a practice space and the games first challenge. Version 1.1 of *Control* ran in windowed view instead of the intended full screen mode due to the limitations of the Stencyl 3.0 beta as it was at that time. As a result, the mouse cursor was fully operation as *Control* ran, creating an unintended and non-functional apparent affordance where it seemed that the start button the title screen was mouse operational.

The lack of easy hit targeting and a clear visual feedback mechanism throughout was also frequently mentioned as a source of game-play frustration. Most often this was expressed non-verbally or through expletives as the gameplay videos progressed, with players remarking exacerbated upon defeat on their progress, or lack thereof:

"game over energy, god dammit!" [183].

"I'm not going to lie, it isn't clear if I am doing anything right, why is he only using certain fingers, is there more than one button I'm supposed to be pressing? Who presses buttons like that? Use your index finger like a normal person" [141].

"Time's up, crap!" [175].

It's like, how is this possible, seriously? i'm just having trouble like, getting past the first level . . . I'm almost there, oh god, with one second left. Ok, there's a lot more time on this one. The first level is so unforgiving with only 20 seconds I'm sure this isn't going to be much better" [187].

*Control's* accessibility theme was remarked upon by two of the reviewers, who made the link between the games extreme difficulty level and the needs of gamers with manual dexterity issues:

"The new games have had like a really oppressive history for people with disabilities, the controls have gotten even more and more precise. If you're missing a finger, what are you going to do?" [87].

“So this is why we need Able-Gamers . . . puts a lot of big ideas into perspective for a lot of able gamers and I think that’s an amazing place this reaches into . . . I like the idea that the game is harder to control than in real life, the game actually makes life more difficult” [159].

“This one just sort of make you think about controls I guess, make you appreciate your fingers” [173].

Overall, among the video reviewers there was a mixed range of responses. It is understandable that for the gaming audience playability is the number one priority, and this can only be offset to a certain amount by the concept. That said, the indie game space is slightly more tolerant of alternative game play ideas. Overall, the range of views was welcome.

Regarding *Control*’s effectiveness as a game, Jim & Nathan offered opposing viewpoints:

“That’s a really satisfying game, it’s a really simple concept”  
 “That’s bull” [87].

Despite possible damage to his eardrums, Melcadrien remained somewhat open to *Control*:

“I mean I think it’s a nice experiment, but it needs work or it’s a bad experiment” [124].

Similarly Abatage was tentative in his praise:

“I kind of like this, but it’s not my thing, it’s way too confusing and the precision nature is a little bit against the way my brain works, because I’m not a precision kind of guy. Having said that, it’s pretty cool, its a nice idea, I like the concept behind it” [183].

The video reviews provided honest, often visceral accounts of gameplay from a first person perspective. The time taken by all to screen-cast their views was appreciated, proving a valuable insight into how the game translated to the home environments of those who downloaded it. In response to user criticisms of the tape loader effect sound levels, version 1.2 toned down the volume, and also introduced an additional message on the caution screen advising the user to adjust their volume. Version 1.3 removed the misleading presence of the mouse cursor by introducing fullscreen mode.

#### 6.4.5 Competition Jury Feedback

*Control* was entered into both the IGF / Independent Games Festival 2014 and Indiecade 2014. While it was not nominated for an award or festival selection by either event, the anonymous review process yielded helpful feedback and insights.

In total there were five reviews received, four of which provided considerably detailed feedback. The festival judges raised similar observations to the website and video reviewers concerning *Control*'s steep learning curve.

"This game was super interesting for me because of how often controllers/interfaces are taken for granted in video game design. In particular, I find this game has the potential to create conversations around accessibility and approachability of controllers" (Indiecade reviewer 1, 2014).

"It was definitely a frustrating game! The audio/visual of the error presses really matched how I felt. The controls felt just alienating enough to be always present in my particular actions with the digital hand" (Indiecade reviewer 1, 2014).

"I think this is a really interesting idea for a game, but unfortunately (perhaps ironically) the controls need serious tuning . . . as it stands, the game is frustrating- frustrating, rather than good-frustrating, if you know what I mean" (IGF reviewer 1, 2014).

"The concept of the game is fun and thought-provoking. In my case the game was played on a macbook using keyboard controls. It was very hard to succeed even in early levels on that device. Is it artistic intention, having in mind the subject matter of the game? If it is not, it will be worth to test the controls of the game more deeply in order to maximize accessibility. Documentation, research and look and audio are strong and provoke a general curiosity in the mentioned subject of the "limitations of the physical interface" (Indiecade reviewer 2, 2014).

"I think that it's possible this game was better in theory than in practice. I do like the basic idea of taking a critical stance on control in games and the idea of making the control of a game the specific target of play, but somehow it doesn't come together for me, as a game, as something that I'm finding very engaging or thought provoking . . . I didn't nominate the game for any award, but I appreciate

that it was made with such thoughtfulness nonetheless” (IGF reviewer 3, 2014).

#### 6.4.6 *The Exhibition Environment as an Interface Layer*

At the time of writing, *Control* has been exhibited at nine different public exhibitions across three continents. Even though each of these events falls under the broad description of an exhibition, they each vary in approach. These range from events that highlight and promote the independent games scene as part of the broader videogames industry, such as A MAZE. / Berlin, the EGX Leftfield Collection, and Out Of Index, to art-based academic enquiry models such as Vector Festival, Blank Arcade, ISEA, Game on! el arte en juego, and Art.CHI. Presentation formats vary from traditional gallery spaces to setups resembling computer science labs. Critical to the success of both styles is the participation of the public and their engagement with and experience of the work presented.

In all user contexts, whether it is at home or in public, the environment both in terms of situated space, and the platform through which *Control* is experienced each add their layer to the experience. In an art gallery context *Control* exists not just as an interactive piece, but also without user interaction by contributing to the audiovisual aura of the group exhibition space.

#### 6.4.7 *A MAZE. / Berlin*

*Control*'s first exhibition and festival appearance was as a finalist at the A MAZE. International Independent Video Game Awards (2014) in Berlin, Germany. The exhibition space at Urban Spree is a warehouse that has been converted into a live events venue and art space. *Control* was installed on a PC with an industrial level monitor sat atop a stack of palettes, in keeping with the rough around the edges warehouse aesthetic (Figure 45). This curation styles strikes a balance between the art gallery space and computer lab environments.

Not only was it the first time *Control* was exhibited publicly, but also the first outing for its fullscreen implementation, as well as the first time it was tested using a joystick instead of a keyboard. Since native joystick support was not implemented, the key mapper software Antimicro was used, allowing the joystick and action button to emulate the arrow keys and spacebar (Figure 46).

A MAZE / Berlin is a showcase not just for the finalists, but also for a large selection of upcoming independent game releases, and as



Figure 45: *Control* in-situ at AMAZE. / Berlin, in fullscreen mode using an Atari 2600 joystick.

such the space was filled to capacity. The exhibition space also doubled as a concert venue, hosting a chiptune rave each night, meaning that the exhibition pieces were subjected to an extreme form of stress testing by the revellers.

The durability concerns of Nintendo's engineers mentioned earlier that led to their forgoing joysticks for more durable directional pads during the Famicoms development were realised when *Control*'s Atari VCS style joystick did not survive more than a day. Following the joystick break, *Control* was reverted to keyboard control, with neon stickers used to highlight the functioning keys.

The presence of the escape key places a certain risk in exhibition space. By allowing a very basic technician level control in close proximity to the player inputs, the likelihood of the player accidentally ending the program is introduced. This can be remedied by two methods. One solution is to physically remove or block the escape key. A second fix is to program a keyboard combination requiring deliberate action to quit the game.

A MAZE. / Berlin was a major validating moment for *Control*, establishing the project within the worldwide indie game space, and allowing it to gain traction and momentum as a touring art piece. Taking part in the exhibition and speaking with the other creators and the playing public provided insights into the state of indie game





Figure 46: A player interacting with Control at A. Maze / Berlin (2014).

industry, including promotional and production strategies that would feed back into further dissemination activities.

#### 6.4.8 *Vector Festival, Toronto*

*Control*'s second public group exhibition was as part of 'To Utility and Beyond. Interface Experiments in New Media and Game Art', which launched as part of Vector Festival, Toronto (2015). The remit of the exhibition was to survey "recent works by a selection of international new media artists and game makers who explore these and other questions through playful, critical, and self-reflexive experimentation". Vector lies at the intersection of new media art and video game art. It intentionally doesn't lean more in one direction than another, keeping an open mind about the evolution and crossover between both.

Vector Festival took place over a four day period, with an involving programme that included talks, workshops, and performances. The exhibition launch coincided with a panel talk titled 'Interface Experiments in New Media and Game Art' featuring the artists and visitors to the exhibition. A recurrent theme throughout the panel talk was that of the environment as interface, as defined by physical space but also ideological constructs.

The *Control* installation at Interaccess gallery was very much in the style of traditional art gallery presentation, with the game controller placed on a blank plinth at standing level, while the flatscreen monitor attached to the wall reflected the interactions of the user. The plinth doubled as a cover for the laptop hidden underneath (Figure 47). The game audio was routed through the monitor with and kept to a moderate level so that it didn't clash with the other works. This approach allowed users to sonically experience the blurring of the boundaries of each exhibition piece while walking around the exhibition space.



Figure 47: Standing level *Control* install with keyboard and wall monitor at Vector Festival (2015).

Similar to A MAZE. / Berlin, the Atari VCS replica joystick installed for Vector broke in the early stages of the exhibition. It was replaced with a wireless keyboard. Engaging with the keyboard is done so in a flat, downward motion as opposed to the VCS joystick that is held in both hands while operated using the thumbs. Since the plinth was at arm height already it meant that keyboard use in this instance was comfortable for the users.

The Canadian audience were undeterred by *Control*'s difficulty level, and there was a notable level of engagement on the exhibition opening night (Figure 48). Vector Festival is also the only space where I witnessed a member of the public completing the game (Figure 49), when asked how he felt after completing *Control* the participant remarked "now I'm free from it".





Figure 48: A crowd gathers to watch a *Control* gameplay session at Vector Festival (2015).

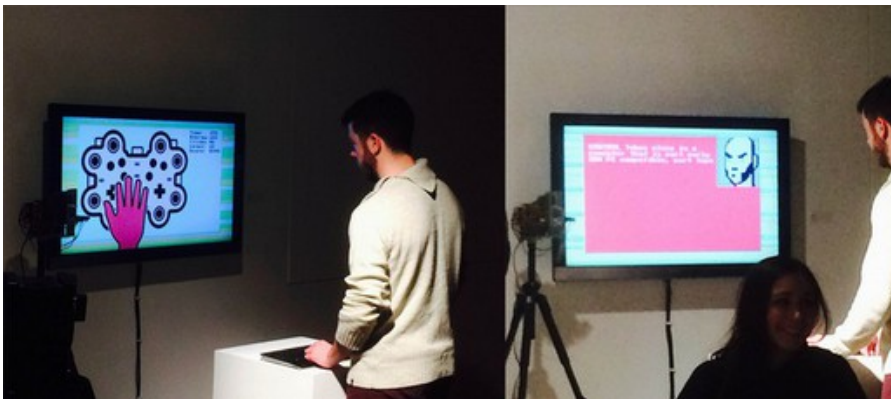


Figure 49: A determined player completes *Control* at Vector Festival (2015).

#### 6.4.9 Materiality, Galway

The Materiality exhibition (2015) curated by Tom O'Dea featured a mixed media selection of artworks centred around the theme of digital materiality, from projection mapping and traditional painting, to edible and scannable consumer critiques. *Control* occupied a central space on the exhibition floor (Figure 50).

The widescreen aspect ratio was squashed to 4:3 proportion on a vintage JVC cathode ray tube monitor, with no detrimental impact to the visual experience. This screen was perched atop a blank white plinth concealing the computer and speakers. A replica VCS joystick was connected by a long USB cable to the plinth. This was the third time an Atari joystick was used in an exhibition space, and while a keyboard was kept on standby, this time it survived the crowd, perhaps a reflection of the relaxed pace of the exhibition. For this exhibition as with Vector Festival and A MAZE. / Berlin, a keyboard



Figure 50: *Control* as part of the Materiality group exhibition, NUI Galway, (2015).

was kept as backup, as consumer level plastic joysticks are less than durable under repeated exhibition use.

By concealing the computer and surrounding the joystick and visual display with a blank white colour scheme, the input and feedback mechanisms were highlighted with the joystick clearly communicating its control functionality. The white rectangle of the floor space spills the plinth's form outwards, marking a boundary zone for engagement. Meanwhile the brightness of the strobing images on the CRT and the looping chiptune music act as an attract mode towards the space.

Since the visual display and controller were placed at floor level, visitors to the exhibition were forced to engage with the piece in a crouched position (Figure 51). There is a sense of symmetry and balance in this arrangement, both in the forms of the installation and visitor as faced opposite each other, and also in the sense that the human must literally stoop down, literally lowering their level as they try and reach a communicative understanding and symbiosis with the lo-fi computational form presented through the *Control* installation. The awkward crouched position coupled with the control scheme's high learning curve mean that without perseverance the dialog between both parties proves short-lived.

#### 6.4.10 *Art.CHI, Seoul*

*Control* has been exhibited twice in Seoul, South Korea, for Art.CHI (2015) and Out Of Index (2015). Art.CHI was a workshop of interac-



Figure 51: A visitor engaging with *Control* at Materiality (Galway, 2015).

tive media works themed around the convergence of human-computer interaction and new media art, as part of the ACM CHI 2015 conference. The 2015 edition of the workshop took a novel approach to presenting the featured artworks in the form of a virtual exhibition that in itself was presented as an academic paper at CHI.

The Embodied Exhibit created by the Interface Ecology Lab at Texas A&M University took the form of both a situated installation at Art-CHI and an internet hosted experience that lives on beyond the workshop [108]. The Embodied Exhibit showcased Art-CHI works in a virtual digital space projected onto a large scale screen that was navigated through using Kinect enabled gesture controls.

This exhibition style bridges the gap between online and physical modes of curation. It also effectively negates many of the logistical concerns relating to the physical transportation and display of artworks associated with setting up an exhibition. Inclusion in the Art-CHI was a welcome broadening of the scope of my research output, while also proving beneficial in terms of exposure, and network building.

#### 6.4.11 *Out Of Index, Seoul*

Out Of Index (OOI) is a festival that promotes experimental gameplay approaches, dedicated to expanding the boundaries and language of game interaction. The event was held at Google Campus Seoul, and with the exhibition preceded by a series of artist talks, which was facilitated by a mix of pre-recorded and live presentations.

Out of Index is notable for its extensive use of online media, including a live broadcast of the event via the game streaming service Twitch, and a dedicated YouTube channel. This media coverage is further augmented by social media posts from the attendees, all of which served to bring as much of the experience possible to me across the internet.

The exhibition set up was very much in the style of an online gaming event, with desktop and laptop PCs distributed around the space alongside ample helpings of free pizza. The PC that *Control* was installed on had a second monitor installed providing a mirror of the game action for interested onlookers (Figure 52). The setting is very much an unpretentious one, and from online coverage of the event it is clearly evident there is an atmosphere of energy and exuberance. Indeed OOI is described in some promotional material as a showcase rather than an exhibition.

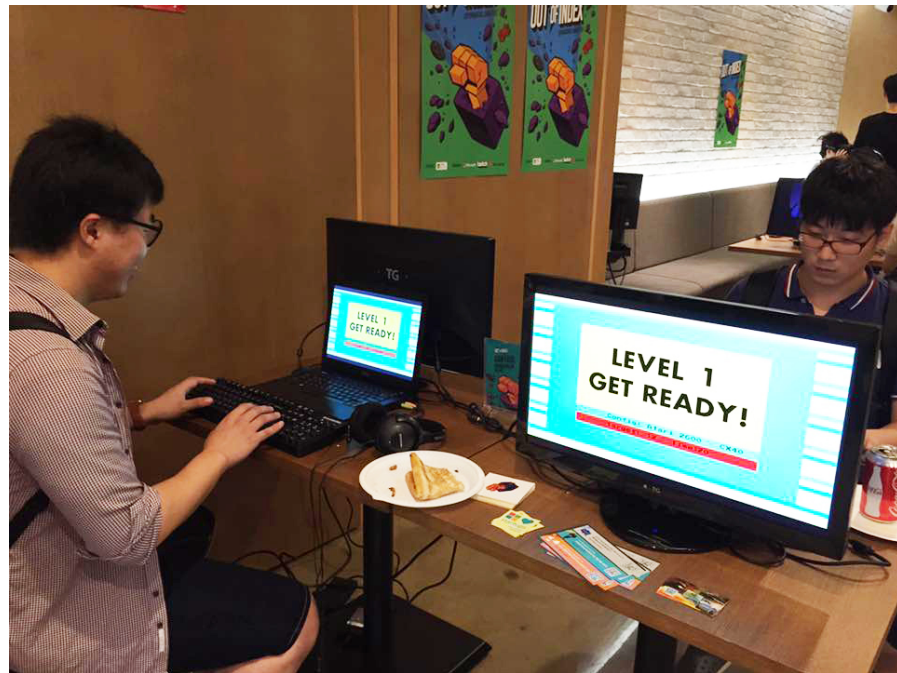


Figure 52: *Control* running from a laptop with a mirrored display at Out Of Index (2015). Photo © Google Campus Seoul.

South Korea has a strong culture of e-sports, and this influence is shown by the running commentary in English provided for the live stream. In addition to the commentators own views, the livestream also communicated across the reactions of the audience. There is a particular moment where the audience simultaneously gasps and laughs in reaction to the final level of *Control* (Figure 53). This was certainly a moment of affirmation, as level 10 is intended to represent an extreme point in the point of controller evolution, bordering on

the absurd.



Figure 53: The audience at Out Of Index watching a video presentation of *Control* (2015). Photo © Google Campus Seoul.

The commentators for the Out Of Index Live Stream [138] translated reactions from the presenters during *Control*'s feature, while providing their own feedback. These included remarks about controller evolution, the games extreme difficulty level, and how the steep learning curve of the constrained control scheme affords a critical view of the interface link:

"That was pretty cool. You got to advance through all the different screens from all the eras, starting at the Atari 2600, going to the Famicom, I think even I saw a PlayStation 1 controller in there at some point . . ."

"obviously it looked pretty complicated, you know how complicated it is to press those buttons . . . even watching that made me all frustrated and flustered . . . the guy who was running this gave it a try, he was getting so super frustrated with the game . . ."

"It is doable, it is possible, but it's insanely hard . . . we all use computers, and we're used to clicking on things, but the idea of using a virtual hand to click on . . . well its really interesting, it takes the idea of using a hand like this and it takes a totally new perspective on how one might interact (translates quote from the festival booklet) 'are



we really communicating with the computer' . . . again, artists man! these people with their own visions making these games!"

#### 6.4.12 *Control* at METEOR Tokyo, 2014

<sup>10</sup> A demake is a remake of a modern game for an older platform.

The annual My Famicase exhibition was founded in 2005 by METEOR, Tokyo. It invites fan-made concepts for 8-bit Nintendo Famicom game cartridge labels [152]. Some are completely fictional titles, while others are conceptual conversions and demakes<sup>10</sup> of existing videogames. For My Famicase 2014 *Control* made the transition from art game to game art as a cartridge label concept (Figure 54a). The design was included as part of the final group show at METEOR's exhibition space (Figure 54b).

The label displays the platform appropriate level 2 scene, modelled on the Famicom controller. As a tangential practice output from this research, it imagines *Control* as an 8-bit conversion tuned down to the 8-bit Nintendo system's aesthetic, with the onscreen world mirroring that of the human to Famicom controller link, forming a closed loop as long as gameplay continues.



(a) *Control* cartridge artwork.



(b) A section from the My Famicase exhibition.

Figure 54: *Control* as a Famicom cartridge game concept at METEOR Tokyo (2014). Photographs by Daryl Cole.

### 6.5 FURTHER IMPLEMENTATION POSSIBILITIES

As seen earlier in this chapter, the live installation permutations for *Control* are numerous, and shaped by the curator and local environment. It is envisioned that further public engagements featuring *Control* will explore new presentation modes across multiple input and display platforms, including large scale projections and across mobile

platforms.

During *Control*'s pre-release phase a HCI designer working in the field of medical computing devices commented on a preview image posted online. He proposed that the game premise could be applied to a virtual testing ground for hospital equipment, allowing the testing of user interactions without fatal consequences for their accidental misuse.

“Not something very serious for CHI+MED, putting one’s life in the hands of anything I’ve had a hand in would be rather worrying. There’s also a Campaigning Game aspect to the project to engage a wider audience in issues around the rapid proliferation of user-interfaces in medicine, a context in which it wouldn’t be a fun game at all if a confusing controller caused the player to “lose a life” :-O [161].”

El Pixel Ilustre put forward an idea for *Control*'s further evolution that was been considered, but ultimately dropped, that of playing a videogame inside of the game with the virtual game controller:

“I would ask more of a step by Control. I would find it more interesting if it didn’t just consist only in pounding the buttons as a pileup of Simon, but we were actually able to play tennis or Pac-Man using a hand that’s not ours. A game consisting of controllable hands that are playing another game. Inception,” (translation) [79].

While *Control* focusses on game controllers, the fact that the keyboard is the default interface is not directly referenced. This was highlighted in feedback from Indiecade:

“The lack of acknowledgement of using a keyboard, which is its own controller, and how that effects the game. This game is about controllers, so, why ignore that meta element of needing one to play.” (private communication, Indiecade, 2014).

Despite the meta message of the onscreen controller echoing the physical one, there is still a disjoint that has to be filled in through the mind of the user, whether they are using the keyboard to control any of the levels, or a single button game controller. *Control*'s self referential interface link is effective to a point, but however still requires a suspension of disbelief.

All feedback in this evaluation is drawn from material either recorded by users, event organisers, or observed first hand by the author. The

inclusion of online analytics as part of the games code could reveal further insights into user engagement, including duration of play and button hit frequency.

The level ten OctoPad concept has been favourably received, producing a physical model of it that people can literally get to grips with would represent a tactile sculptural embodiment of game interface complexity. Indeed, a simultaneous two-player version of *Control* could add a fresh competitive dimension to the experience also.

A further conceptual augmentation for *Control* is possible by porting the game to mobile touchscreen platforms. This would involve eschewing the obvious mode of interacting with the onscreen gamepads via direct touch controls. Instead the player controls their hand avatar through the onscreen representation of a joystick and action button. This approach would mirror how arcade control schemes are commonly ported to touchscreen, while meditating on the touchscreen interface as a glass barrier between the real and virtual worlds.

## 6.6 CONCLUSIONS

Initially the [background context](#) for *Control* was set, outlining the technical, historical, and theoretical background for the project. As an artefact that combines interaction design and indie game design it reflects a diversity of influences, bringing these to focus as a self-reflexive new media art experience.

This was followed by the [creative process](#) behind *Control* from pen and paper concepts to the digital authoring stage, detailing the technical, aesthetic, and interactive considerations taken while developing the project. It also provides a detailed walkthrough of the game experience.

Finally *Control* was [published and evaluated](#), considering reactions from audiences in the academic, indie game, and new media art spaces. As an art-game designed to both frustrate and provoke discussion it has succeeded, embodying the resolution divide between the real and virtual worlds. Feedback from the public has posited further directions for the project's evolution, while each exhibition curator has added a new dimension to how *Control* is engaged with through their installation design.

The culture from which the participant approaches the artefact affects their interpretation, whether they are a gamer, art enthusiast, interaction designer or otherwise. Playability is the crucial ingredient



for the indie game audience, with the disconcertion caused by lack of conventional in-game feedback offset to a certain amount by the game concept and challenge posed. However the indie and art-game niches do embrace experimentation, and so the non-standard gameplay has served to distinguish *Control*, evident from its festival selection run.

The conceptualisation and creation of *Control* were important stages, but without audience participation the piece would have not realised its full potential, as it was built for engagement. Additionally, taking *Control* into the public space brought to light several possibilities for further augmentation of the project. *Control*'s distribution process was a positive learning experience in research promotion and dissemination across discipline boundaries, one that positively influenced the remaining practice and theory components of this study.



ARTEFACT B: ARCADE OPERATOR

---

*This Book will not, nor is it intended, to: Make you a technician  
Turn you into an engineer  
Fix all your game problems  
Repair printed-circuit boards, or  
Make coffee.*

*Overall, we hope this book helps you feel more confident with the  
techniques, tools and terminology associated with coin-operated electronic  
games. We wish you good luck and good troubleshooting!*

**— Atari, Inc., Coin-Op Field Service, 1980**

## 7.1 INTRODUCTION

*Arcade Operator (Test ROM Edition)* is an experimental art game where the player takes on the role of a video game Arcade Operator. Instead of playing the coin-ops present in the diegetic space of the onscreen arcade, the player must interface with the game cabinets as both operator and technician.

*Arcade Operator's* style of interaction is closely modelled on the side-scrolling brawler sub-genre of arcade gaming, switching the user context to a non-gameplay mode of interfacing with arcade video game platforms, albeit in an abstracted form through an arcade play mechanic.

While *Control* articulated the limitations of physical game controllers through a down-sampled onscreen representation of the hand-to-joystick and gamepad link, *Arcade Operator* uses arcade-brawler gameplay conventions to abstract the act of manually interfacing with arcade circuitry.

*Arcade Operator* is also a critical artefact, a metagame using the medium of the arcade video game interface to reflect on the software and hardware of game interfaces. Specifically, *Arcade Operator* reflects on the user context of interfaces by articulating the non-play actions of an arcade operator through the control schema and visual interface conventions of a side-scrolling, arcade-brawler aesthetic.

### 7.1.1 *The Arcade, Critical Play, Self-Reflexivity, and the Metagame*

*Arcade Operator* is a self-reflexive critical play artefact, a metagame designed to investigate user context and interface conventions in arcade video games, and is the second artefact of three artefacts that comprise the material thesis of this practice-included study.

In *Metagaming*, Boluk and LeMieux present several definitions of the term metagame; they refer to a 2011 blog post by Andy Baio in which he describes metagames as “playable games about video games” [23, p. 6]. *Arcade Operator* further focuses this definition as it extends the concept of metagaming to consider the physical upkeep of video game hardware, and not just game software.

Regarding critical play, Flanagan states that it “means to create or occupy play environments or activities that represent one or more questions about aspects of human life” [59, p. 6]. This definition of critical play relates to philosopher and game designer Stefano Gualeni’s definition of self-reflexive games as “video games that are deliberately designed to materialise, through their gameplay and their aesthetic qualities, critical and/or satirical perspectives on the ways in which video games themselves are designed, played, sold, manipulated, experienced, and understood as social objects” [70].

Through the occupied environment in *Arcade Operator* is the diegetic space of the arcade-brawler genre, the game critiques its tropes and limitations to examine game software and hardware by investigating the role of the arcade operator as facilitator of arcade gameplay. By taking the arcade interface and simultaneously presenting it as an enabler of both play and non-play, *Arcade Operator* subtracts several core elements from the brawler mechanic, namely the enemies and the brawling. In doing so, the game emphasises the repetitive nature of the operator’s task, and reimagines enemies as time and resources.

### 7.1.2 *Interface Context*

While current game developers and engineers construct game environments through software interface contexts, the arcade operator who runs the arcade and maintains the machines has a unique, non-play level of interaction with the arcade cabinet hardware. Operator-level interfacing with the arcade platform ranges from routine tasks, such as emptying the coin-tray and configuring game values via dip-switches, to more complex tasks, such as installing, troubleshooting, and repairing game printed circuit boards [16]. To the playing and paying public, arcade video game cabinets represent closed-off,

black box computing systems. An arcade cabinet's inner workings are strictly utilitarian, right down to the unadorned, exposed nature of the cathode ray tubes and PCBs (Appendix B). *Arcade Operator* is an experiment in taking the repair and maintenance tasks of the amusement arcade operator and making the associated processes and platform components visible to the arcade player.

### 7.1.3 *Developer Level Context*

The black box of the arcade game as a computational platform engaged with in non-play contexts demanded access by the developer or operator, but is now accessible to the wider community of preservationists, artists, and hackers. In the chiptune music documentary *Digging In The Carts*, Junko Ozawa of Namco's sound team details the process of creating music for Capcom's CPS1 [48]. Compositions were first committed to paper-based notation, and then transcribed into machine code specific to the arcade system sound chip used. The finished machine code was then burned to EPROM chips that were then physically attached to the game board for testing. Machine code programming removes the layers of abstraction of visual programming, directly addressing an assemblage of components and circuits in what is known as 'bare metal programming'. In the case of classic arcade games hardware was often designed around the game, thus demanding custom approaches for each bespoke computing platform.

### 7.1.4 *Interface Context: Player, Operator, Artist*

The role of the interface is to facilitate communication, whether that is between a human and machine, between two or more humans as mediated by a machine, or between machines or the internal mechanisms inside a single machine [10, p. 117]. An effective interface naturalises this link, with the most usable solutions ensuring that the conversation flows as effortlessly as possible [77, p. 21]. The abstracted level of interaction with the inner binary processes of computers provided by GUIs and voice driven interfaces allows access by the widest market possible, those who are not involved with the creation of computational platforms, thus ensuring maximised sales.

The interface level of the pay to play arcade videogame player is an intentional extension of this consumerist ideology, however video games usability and playability are not mutually inclusive. Playability demands a certain amount of challenge, enough to frustrate but not enough to deter continued engagement. The player level interface

is one of a number of layers of interfacing that are possible with the same gaming platform, each level accessibility dependent on the context of the user.

To the playing (and paying) public, arcade videogame cabinets represent closed off, black box computing systems. The arcade operator who runs the arcade and maintains the machines has a unique, non-play level of interaction with the machine, performing repair and maintenance tasks on the same hardware. Similarly game developers and engineers connect with the same computational system through different interface contexts, while game art practitioners use gaming platforms (both hardware and software) as raw materials for their own unique creators context.

At its most basic level, *Arcade Operator* is an arcade game about fixing arcade games. As a self-reflexive artefact it reimagines the arcade brawler mechanic as a means to experience the non-play interface context of arcade repair and maintenance. By engaging with the game players learn that the operator role exists and are made aware of the modular nature arcade machines, learning about the basic hardware anatomy of ‘black box’ arcade platforms.

#### 7.1.5 *Arcade in Arcade*

One of *Arcade Operator*’s inspirations is the end sequence for *Golden Axe*, released by Sega in 1989 as a response to *Double Dragon* (Technōs, 1987). It took the established side-scrolling, beat ‘em up game and fused it with the magic and sword elements associated with the fantasy genre to create a barbarian-themed, hack-and-slash finale. Its ending sequence initially plays out as expected: after Death Adder is defeated and both the King and his daughter Yuria are released, players are congratulated with the completed world map, signed off ‘fin’ with a quill pen. It’s a brief, but suitable moment of closure.

The screen then fades to black, transitioning to a scene at a Sega amusement arcade where three children are gathered around a video game coin-op cabinet identified on a poster as “Great Axe” (Figure 55a). Smoke erupts from the screen as one by one, the villains of *Golden Axe* jump out of the machine and chase the kids outside and down the street, followed in hot pursuit by the heroes (Figure 55b). This representation of the normal situated space of the *Golden Axe* arcade machine within its own game world humorously brings the game characters into the universe of the players; game immersion normally entails players immersing themselves into the world of its protagonists, but in this case, the game characters emerge into the

world of the player, reflected in a detached third-person view through the visual and diegetic interface of the arcade video game itself.



(a) Golden Axe as 'Great Axe'.



(b) The cast escape the arcade.

Figure 55: *Golden Axe* end sequence.

#### 7.1.6 Arcade as Pseudo-Simulation

*Arcade Operator* offers a low-resolution approximation of a real-world task via the arcade interface. It uses the 16-bit arcade video game aesthetic as a vehicle for its simplified take on modelling a real task and environment.

Yu Suzuki's Sega arcade titles including *Hang On* (1985), *Outrun* (1986), and *G-LOC: Air Battle* (1990) deliver the immersion of motorcycling, driving, and flight to the amusement arcade space. Each game is accompanied by enhanced action aesthetics, minus the steep learning curve associated with their real-world equivalents. Their bespoke arcade cabinets provide a bolstered sense of connection by basing the arcade control system around the literal, real-world machine interface the game is modelled on. The attract mode for Suzuki's *After Burner II* (1987) emphasises the specialised control mechanism and human-game link, breaking the fourth wall by directly picturing the player and joystick in-game to sell its flight sim style interaction (Figure 56).



Figure 56: *After Burner II* attract mode.

During the 1980s and early 1990s, Codemasters published a series of budget-priced games for 8-bit and 16-bit home microcomputers using *Simulator* as the title suffix. These titles included *BMX Simulator* (1986), *SAS Combat Simulator* (1988), and *Pro Tennis Simulator* (1989). The use of “simulator” in the title suggested a level of realism on par with industry level flight simulator systems. In truth, the titles are lo-fi arcade-style abstractions. *Pro Tennis Simulator* is described by comprehensive game database MobyGames as “bare bones action for 1 or 2 players” [145]. Devoid of first-person immersion, let alone any remote resemblance to their real-world inspirations, their gameplay is primarily characterised by reflex-driven action and basic audiovisuals.

#### 7.1.7 *Repair in Arcade Games*

Another point of reference for *Arcade Operator*’s design is that of repair as gameplay, exemplified by Lucasfilm Games’ *Night Shift* (1990). *Night Shift* is a game in which the player character, Fred or Fiona Fixit, must maintain a factory by jumping from platform to platform, ensuring all the switches and levers are at the correct setting. All factory operation tasks are reduced to a single action button, and four arrow keys move the character around the gamespace. While not an arcade-born game, it does share several gameplay characteristics with arcade platformers.

In the context of arcade genre repair games and *Night Shift* specifically, it is difficult to ignore *Fix-It Felix Jr.*, the faux-classic arcade game invented for the 2012 Disney movie *Wreck-It Ralph*. As with *Night Shift*, gestures associated with manual labour are reduced to a single action button control. Each successful repair action produces a chain of visual feedback as Felix moves frantically, partly obfuscated by an animated cloud of smoke and building debris.

#### 7.1.8 *Design Constraint Considerations*

It was necessary to implement several constraints right at the start of the design process, since there were so many possible directions that the game build could take. Parameters were set not only in terms of the game’s audiovisual look and feel, but also regarding the gameplay aesthetics and interface style. *Arcade Operator*’s gameplay constraints were modelled on those of the side-scrolling brawler arcade sub-genre mechanic. Typically, this style of gameplay features a character traversing a scrolling play field from left to right, using well-timed attacks and jumps to overcome enemies and progress onwards.



For *Arcade Operator*'s take on this action genre, two main constraints were implemented: the first of these self-imposed limitations was the omission of any enemy characters. This condition was inextricably linked to the second constraint, which was to include no combat or violence. Power ups and weapons are replaced with spare parts.

Anthropomorphising the arcade cabinets was ruled out to strike a balance between real-world authenticity and 16-bit abstraction. The static cabinets don't move around, and they don't attack. Instead of damaging them, the player undamages the cabinets by using the action button to engage in repair tasks. Successful repairs are reflected by the repair bars for each coin-op component moving from red to green. Fully-repaired cabinets change visually from plain blue to full colour. When all cabinets on a level are repaired, the game progresses to the next level.

#### 7.1.8.1 *Condensing Arcade Repair to an Arcade Control Scheme*

In arcade fighting games, a single button push can represent a variety of complex, sequenced actions. Such operations can include attacking an enemy, picking up a weapon, opening a door, breaking a crate or barrel, administering first aid, or as in the case of *Final Fight* (Capcom, 1989), eating a roast turkey randomly found on the street to replenish health. *Arcade Operator* takes the skill-set of repairing arcade video game cabinets and transplants it within the brawler mechanic. *Arcade Operator*'s control scheme is limited to eight directions of movement and two action buttons, 'fix' and 'crouch'. Pressing both fix and crouch at the same time allows the player to pick up or drop spare parts. The specialised, niche craft of arcade maintenance in its varied guises, including replacing circuit boards, degaussing cathode ray tube screens, and soldering loose wires, are reduced from a sequence of complex actions to, at its most complex, two simultaneous button presses.

Augmentations to this interface style were considered; for example, gameplay could have included multiple choice menus allowing the selection of different repair types. These more complex mechanics were abandoned, as it would dilute the arcade sub-genre with elements unrelated to brawler mechanics. For example, if elements such as revenue generation and stock control were introduced, the gameplay style would move from arcade action to a business management game, lessening the impact of its critique of the brawler mechanic.

## 7.2 PRODUCTION TOOLKIT

The toolchain used to produce the demo mainly used Pixon, Photoshop and Stencyl. The cabinet designs were sourced as 3D models exported from Sketchup to Blender, viewed in GLC Player, screen captured, traced in Pixon, and further animated and edited in Photoshop. The soundtrack was composed with *Little Sound Dj*, with audio effects recorded and post-processed through Audacity.

### 7.2.1 *Concept Origins*

*Arcade Operator* was originally titled *Arcade Game Game*, and was envisioned as a fighting game where the player used special joystick and button combinations to repair arcade games using a similar mechanic to one on one fighting games. In particular it was inspired by the bonus level of *Street Fighter II*, where the player takes a time from fighting human (and inhuman) characters out to forcefully disassemble a Toyota Celsior within a time limit. *Arcade Operator* would instead swap this inanimate opponent from a car to an arcade machine, and have the player interactions build rather than destroy.

The concept moved to side scrolling fighter style template, and eliminated the use of combos, in favour of arcade spare parts used in a similar manner to pick-up weapons.

### 7.2.2 *Initial Sketches*

After a series of concept sketches, the first digital prototype for *Arcade Operator* was rendered as a static image in Pixon at 320 x 240 pixels (Figure 57a), the base resolution for the JAMMA arcade cabinet interface standard [37]. These graphics were then scaled up by 400% and modified from 4:3 resolution to widescreen to accommodate modern displays (1920 x 1280, scalable down to 480 x 320). *Arcade Operator's* graphics stemmed from *Control's* visual aesthetic, using the same early IBM PC derived palette constraints and aliased pixel art graphic style. The home-conversion style aesthetic was also chosen for expediency as well as visual clarity and consistency with the previous artefact.

Figure 57b shows an interface concept where the spare parts are selected by cycling through a horizontal inventory bar, following the weapon selection interface convention from *R-Type* (Irem, 1987). This approach was dropped in favour of directly picking up and dropping the spare parts in a manner similar to arcade brawler gameplay where

only one weapon can be used at a time.

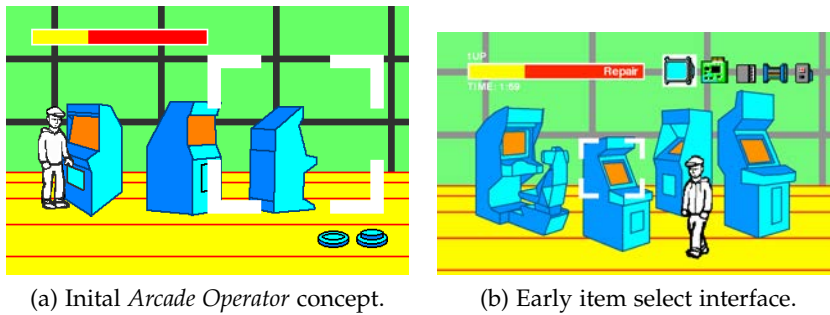


Figure 57: Initial digital sketches for *Arcade Operator*.

As *Arcade Operator* was developed from the initial concept image into a functioning prototype, coding, visual design, and gameplay constraints each influenced each other, affecting how the final product was shaped.

### 7.2.3 Character Design

*Arcade Operator*'s player character was based directly on the author, and was animated in-part by rotoscoping the walk cycle for Jimmy Lee from *Double Dragon Advance* (2003), to allow eight directions of movement within a top down, pseudo-3D perspective. The choice of player character is a reference to the designer's own immersion into the material of the artefact, and willingness to be the test subject for this game experiment (Figure 58). It can also be interpreted as a meta commentary on game art, where the practitioner becomes part of their own creation.

The player character is monochrome, staying consistent with the outlined style of the environmental graphics, in order to emphasise the full colour arcade spare parts carried by the character, and also the animated feedback of the repair operations. As the prototype developed the asset requirements became increasingly apparent, requiring the production of a considerable amount of animation frames. The player character uses 208 unique hand drawn sprite frames, to facilitate movement in eight directions, alongside the carrying and use of each arcade spare part and repair operation.

### 7.2.4 Typography

*Arcade Operator* uses two fonts. The game title logo, and all in-game feedback text used Karmic, an outlined, upper case pixel font, and

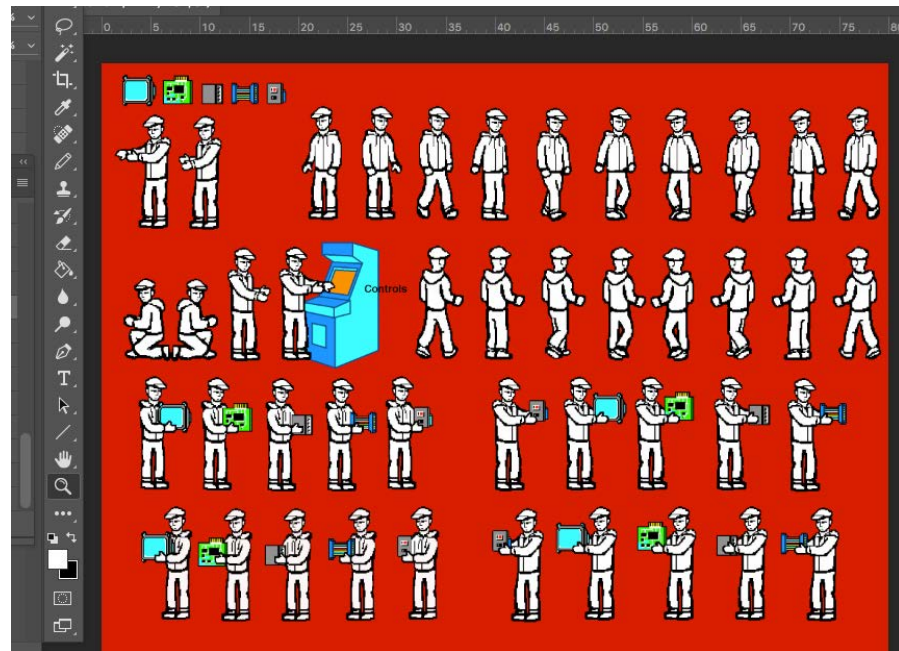


Figure 58: A selection of character animation frames from *Arcade Operator*.

was all manually laid letter by letter out and coloured using Photoshop. All remaining text, including the boot screen and congratulation screen message use the font from Sega's *Wonder Boy* (1987). This text was typeset using Photonstorm's online utility *Arcade Font Writer* [44] and exported to Stencil in .png format.

### 7.3 GAME ENVIRONMENT DESIGN

During the games early development stages several 2D brawler play fields were visually examined to establish whether a common blank template was identifiable for the genre's level layouts. In particular visual overviews were constructed for selected levels from *Double Dragon* (Technōs Japan, 1987), *Golden Axe* (Sega, 1989), and *RoboCop 2* (Data East, 1991) with the aim of establishing commonalities among each in terms of their use of forced perspective. This process of creating the composite level maps involved first capturing multiple screenshots during gameplay through the OpenEmu emulator. These images were then combined together in Photoshop, with their perspective traced as an overlaid layer.

It was found that there was no uniform approach used among the three given sampled games to map out forced perspective in horizontally levels. Each title takes unique artistic liberties to create a sense of depth in their horizontally scrolling playfields within their respective display constraints, neither of which totally eliminate visual perspec-

tive anomalies.

### 7.3.1 Side Scrolling Brawler Perspective

*Double Dragon*'s level 1 background graphics, when seen from a composite view, use parallel projection mirrored on the left and right sections of the game map. However during gameplay, the viewfield is seen in a roving, cropped macro view. This is a necessary compromise to the game engine's lack of corrective scaling of the play field view as the Lee brothers battle through their mission.

*Arcade Operator* adheres to this aesthetic style born of platform constraints. Yet while the 2D brawler perspective defies real world laws of optics [46], it nonetheless demands consistency in how onscreen components are drawn and placed.

In the aforementioned examples, angular, non-organic structures such as buildings provide the most obvious visual aberrations. The garage in *Double Dragon*'s first level typifies this visual property, its diagonals gone askew (Figure 59). Organic backgrounds such as forests are more forgiving, as their irregular shapes don't provide immediately obvious lines of sight. *Golden Axe* takes advantage of this trait, with the fantasy medieval styled world only occasionally punctuated by angular structures that draw attention to its cartesian perspective defying scenery (Figure 60).



Figure 59: Level 1 of *Double Dragon* (Technōs Japan, 1987). This scene presents a centrally ordered view as a composite image, however this is not as evident in the macro eye view during gameplay.

Organic foreground objects, including animated characters create less visual tension, especially due to their movement and random placement. Rounded foreground objects including upright barrels, a staple of the side scrolling brawlers, and small pickups such as the cooked turkey from *Final Fight* blend into their respective scenes rela-

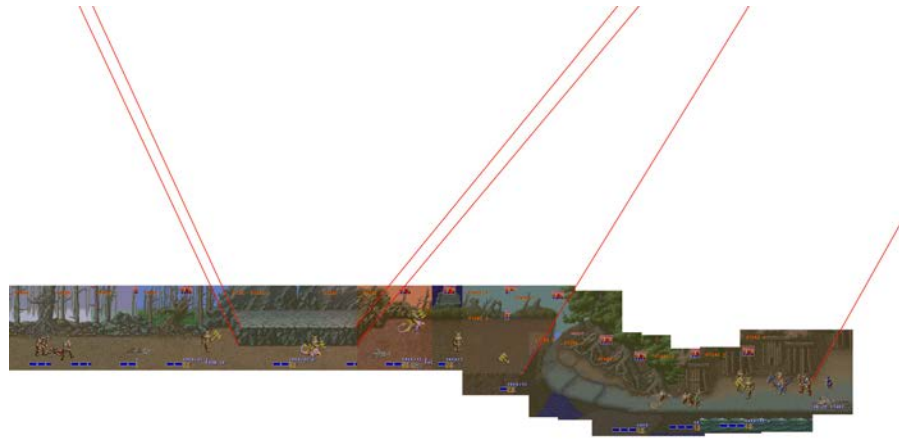


Figure 60: *Golden Axe*, stages 1 to 3. All screens link together cleanly. The environment is very much organic with few angular shapes, this helps disguise the unreal nature of the forced perspective.

tively easily due to their shape. However angular foreground objects including crates and cars are more difficult to disguise, since their placement exaggerates perspective lines further while clashing with lines of sight established by the background.

*Robocop 2*'s second stage is the perfect storm of angular background and foreground objects colliding, providing an ideal reference for *Arcade Operator*'s design as it depicts an amusement arcade (Figure 61). It features rows of arcade cabinets are emblazoned with the Data East logo, alongside a row of Robocop pinball machines. Viewing the complete level design as a singular image makes it clear that the artists planned the stage to minimise perspective issues, with multiple versions of the interactive foreground arcade cabinets drawn and positioned to line up with the static coin-ops drawn in the background. The level design features multiple vanishing points, minimising visual clashes by pausing scrolling to fight groups of enemies where at areas where a single vanishing point is pictured.

### 7.3.2 Environment Implementation

After careful consideration it was decided to render *Arcade Operator*'s arcade cabinet vanishing points at their individual centres, this approach allowing uniform placement of the objects at varying baseline positions along the horizontal stage (Figure 62).

*Arcade Operator* prototype's environment is spartanic, using a grid background a horizontally lined floor to suggest a bare storage warehouse space. This allows the arcade cabinets to take centre stage, while helping mask visual perspective errors associated with the forced



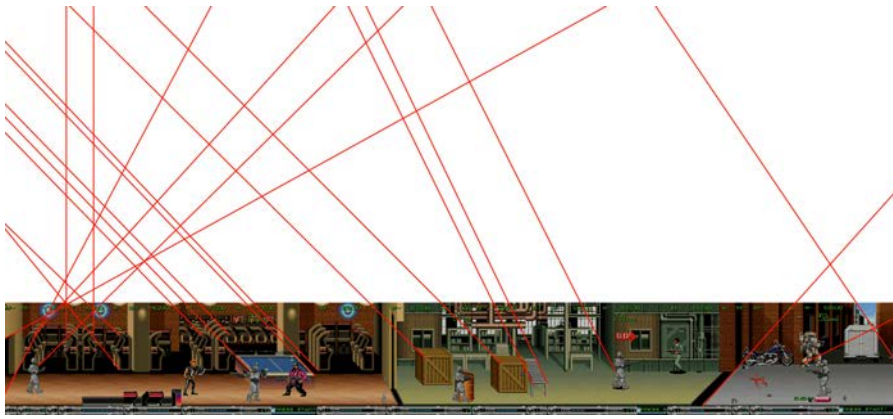


Figure 61: *Robocop 2* by Data East (1991). The level combines angular non-organic elements in both the background and foreground, presenting challenges for the environment artists in the perspective view shown.



Figure 62: An early *Arcade Operator* test level layout mockup with object coordinates marked.

perspective pixel art of side scrolling fighting games. An absence of diagonal lines in the floor design prevents it mismatching with the base of each arcade cabinet. Similarly the unadorned wall design minimises optical dissonance with the foreground arcade machines.

### 7.3.3 Featured Arcade Coin-Ops

Four arcade cabinet designs are featuring in the prototype, Each has a distinct profile that remains recognisable even when their colour schemes and artwork are removed. The arcade coin-ops included are:

- Atari's upright *Pac-Man* cabaret cabinet (1980)
- SNK's Neo Geo MVS multi-game cabinet (1990)
- Midway's *Mortal Kombat* (1992)
- Atari's *San Francisco Rush* sit-down racing cabinet (1996)

While photographic survey material of arcade machines assisted in the initial conceptualisation of the game, 3D scale models from

Sketchup's online library were referenced during the development of the in-game arcade cabinets, to ensure accurate rotoscoping of all the arcade cabinets at uniform angles. This process involved mixing analog and digital, using an improvised paper guide overlaid on the computer monitor to position the models. The correctly angled 3D models were subsequently screen captured and traced in outlined 2D form (Figure 63).

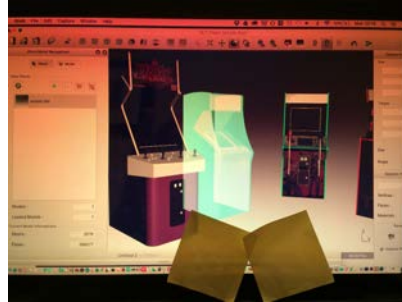


Figure 63: Using paper screen overlays to position 3D models.

#### 7.4 SOUNDTRACK AND AUDIO EFFECTS

*Arcade Operator's* soundtrack was produced in advance of all other digital assets. The instrument of choice for composing *Arcade Operator's* soundtrack, as with *Control* previously, was *Little Sound Dj* running on the 1989 Nintendo Game Boy console. Although an physical Game Boy console was used during the production of *Control's* music, the Game Boy emulator *Gambatte* was used for producing *Arcade Operator's* soundtrack. This decision was made for visual comfort reasons, as it allowed *LSDj* to run in magnified view at full screen on a laptop monitor, rather than the Game Boy's diminutive 4.7 × 4.3cm screen.

Using *Little Sound Dj* through the *Gambatte* emulator also brings the ability to record directly from the system audio into Audacity via Soundflower, with all sound channel mixing performed inside the *LSDj* application. Audacity was used to record, trim, normalise, and save the tracks. Also .wav copies of the tracks were saved for use in Stencyl, with .ogg versions exported for upload to SoundCloud.

*Little Sound Dj* uses 4 inputs; A, B, start and select, each of which were mapped to the MacBook Pro keyboard to roughly approximate the Game Boy button layout. Additionally, a bootleg USB controller version of the Nintendo NES joypad was used to control the emulator, since it closely mirrors the Game Boy's own physical interface.



All voice samples were recorded live and then processed with a bit crusher effect in Audacity to replicate the muffled low-bitrate sound characteristic of 1990s arcade sound hardware.

#### 7.4.0.1 Chiptune Composition

The creative process behind *Arcade Operator*'s soundtrack began with conceptualising track titles for each stage of the game experience. Next followed the production of music for each identified game aspect through an iterative process of improvisation, testing, and editing. At a practitioner level *Arcade Operator* was in part an opportunity to gain a greater understanding of chiptune composition, progressing beyond the four bar loops of *Control*'s soundtrack into more complex musical arrangements.

A major hurdle and subsequent process breakthrough made during *Arcade Operator*'s development was learning how to sequence multiple loops together in *LSDj*. The terminology used in *Little Sound Dj* is unique to the tracker music sequencer interface convention, and so required my adapting to a new technical and musical language.

In *Little Sound Dj* a loop of musical notes is referred to a phrase. Multiple phrases can be linked together into chains. Chains are played from the main song screen, one for each of the four audio channels. A chain lasts for one step, and multiple steps are used to create a track.

Also, before a loop can be composed, the instrument must be defined. Depending on the channel used, this will be either a pulse synth, a waveform, or a noise effect. The sound properties of the instrument are adjusted through parameters such as the envelope and decay rates.

Effects are applied directly to notes in the phrase screen. An effect used frequently in the *Arcade Operator* soundtrack is the arpeggio effect on one or both of the pulse channels. The noise channel was used as a percussive instrument, in of drum samples.

Modifying assigned instruments in *LSDj* is relatively straightforward. Apart from synth sounds, there are also several .wav format sample kits taken from classic drum machines, in addition to voice samples sourced from the 1980s *Speak & Spell*.

#### 7.4.0.2 *Soundtrack - Method*

The following short vignette describes a typical sequence of events when composing in *Little Sound Dj*. This working method starts with selection of a default starting phrase in pulse channel 1, and subsequent placing of four or eight instances of this phrase into a chain, while adjusting the key for each instance. Pulse channel 2 then has an accompanying phrase entered that uses the same key changes. The inbuilt drum samples on channel 3, also known as the wave channel, are then sequenced to compliment channels 1 and 2. The noise channel (channel 4) is then used to layer additional textures that add further character to the 8-bit sound aesthetic.

All the tracks in *emphArcade Operator* follow a 4/4 structure, with BPMs from 90 upwards. The Nintendo Game Boy's signature chip-tune sound was embraced fully for this project, the melodies punctuated by copious amounts of arcade style sound effects. This included the use of the noise channel for explosion and laser fire style percussive sounds. The arpeggio (c) and slide (p) filter settings were used heavily when composing the basic phrases (loops) that were sequenced together in the chain screens.

#### 7.4.0.3 *Reactive Theme*

*Control* featured a reactive music style, switching between variations of the soundtrack that reflect the player's progress and energy level, using 172bpm, 4 bar loops. Each of these themes version shared the same structure but switched instruments, becoming more discorded as the player energy decreased.

During the composition process the function of each song in the tracklist was considered and reflected in the produced sound. For example, **Level Intro** and **Game Start** are both fast paced, with tremelo type effects, and are intended to create excitement and anticipation. In contrast the **Level Complete** track is more relaxed, and offered as a way to relax between levels. The **Level Theme 100** track conveys methodical work, as the operator carefully builds and repairs the arcade cabinets.

Once the initial version of the *Arcade Operator* level theme was finalised, it was duplicated and modified three times, for use when the player was at 75%, 50%, and 25% energy. All the theme variants were linked by shared phrases and melodic characteristics, by swapping instruments, each was changed sonically while maintaining the same structures. As *Arcade Operator's* game mechanic become more fully realised, the 75%, 50%, and 25% variants of the them were dropped.

NUMBER	TITLE	CATEGORY	DURATION
1	Intro Sequence	Attract Mode	0:30
2	Title Theme	Attract Mode	3:02
3	Game Start	Cutscene	0:15
4	Level Intro	Cutscene	0:21
5	Arcade Level	In-game	1:57
6	Game Complete	Victory Cinematic	1:18
7	Options Screen	Menu	1:17
8	Game Over	Defeat	0:21
9	Level Complete	In-game	0:21
10	Level Theme 100	In-game	2:59

Table 4: *Arcade Operator* soundtrack listing and track categorisation.

This is because *Arcade Operator* starts the player at 0% and builds to 100% completion, rather than beginning with the ‘full’ soundtrack. It was reasoned that having the discorded 25% variant of the track introduce the game could prove offputting to players.

The final version of the *Arcade Operator* soundtrack was published to Soundcloud in advance of the game release, totalling eleven tracks running at thirteen minutes and seven seconds. Five of the tracks were used in the Test Rom Edition 0.3, as highlighted in Table 4.

## 7.5 PRODUCTION TIMELINE AND ONLINE DISTRIBUTION

Once *Arcade Operator*’s initial digital concept drawing was completed in January 2015, and the development toolset decided upon, the wheels were set in motion towards implementation of a fully functioning prototype, *Arcade Operator (0.3 Test ROM Edition)*, that was published through indie game portal [itch.io](https://itch.io) in July 2017.

A web presence for the artefact, [kierannolan.com/arcadeoperator](https://kierannolan.com/arcadeoperator), was set up in June 2016 hosting a synopsis of the game concept alongside accompanying screenshots, gameplay video, and the soundtrack. Progress reports were posted periodically to the public on Twitter, garnering interest from indie games, game studies, and retro gaming audiences.

*Arcade Operator* was featured on game art website [Gamescenes.org](http://Gamescenes.org) in August 2017, and as a peer reviewed paper in the inaugural issue of VGA Reader journal, published by the Video Game Art Gallery in November 2017.

## 7.6 INTERACTION WALKTHROUGH

*Arcade Operator* is a one level experimental prototype that reinterprets the sideways scrolling arcade brawler interface, using the arcade interface to deliver an experiential of the arcade interface as defined by user context. It allows players to experience the arcade interface as defined by user context, through the non-play interaction of the arcade operator, albeit through a play interface. The demo's gameplay duration is short, taking place within a 140 second time limit.

### 7.6.1 Boot Sequence and Title Screen

*Arcade Operator*'s boot screen animation ([Figure 64](#)) simulates an arcade BIOS, ROM, and memory check, followed by a display of the current game revision number, and is stated as running on the fictional ZenCom brand, referenced previously in *Control*. The title screen presents the arcade cabinets in an animated sequence with the title text overlaid on top ([Figure 65](#)).

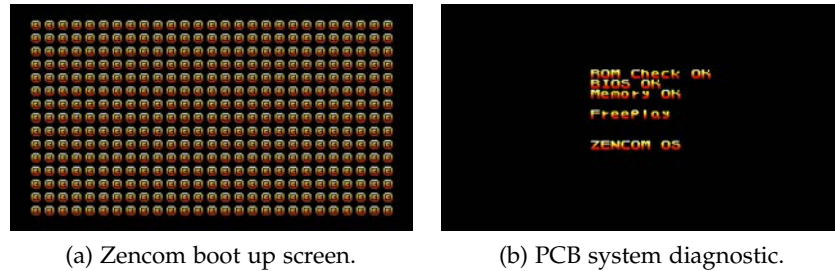


Figure 64: Game boot up screens.

### 7.6.2 Level Introduction

The level introduction screen serves as an instruction sheet, providing a brief primer on the anatomy of the in-game arcade cabinets. It presents labelled versions of each of the constituent components, each linked to their respective zones on a sample arcade cabinet ([Figure 66](#)).



Figure 65: *Arcade Operator* title screen.



Figure 66: Level introduction screen serving as gameplay guide.

### 7.6.3 Visual Interface

Upon starting the demo level, each arcade machine is initially represented as a blank, blue coloured shell. Walking close to a cabinet overlays its repair bars at the top right of the viewfield. A composite repair bar summarises all repair progress across the level (Figure 67).

The score rises in response to each repair made, and is subtracted from if an incorrect spare part is applied<sup>11</sup>. The game world is presented in a slightly off-perspective 2.5D style, inspired by the aesthetic of *Double Dragon* and other popular brawlers, allowing the player to move around the arcade cabinets needing repair.

<sup>11</sup> A bug in version 0.3 causes a fractional score to display at times.

Feedback on player progress is delivered through the static interface in the form of the timer, score, cabinet count, and repair bars, and also through the diegetic interface in the animated feedback shown for each repair interaction. Each collision with a non-repaired cabinet triggers feedback visuals and audio responses that communicate the score increase and the arcade part under repair.

All in-game graphical elements use flat colour schemes, with the exception of the arcade spare parts, their associated static interface icons, and the visual feedback signifying the undergoing and completion of their repair actions. Only the player character, spare parts, and static interface text have dark outlines, this is in order to bring them visually to the forefront of the scene.



Figure 67: *Arcade Operator* in-game view.

The arcade cabinet's collision areas aren't directly highlighted, so an element of trial and error, if not discovery, is involved. The operator fixes the machines by interacting with different collision points on the cabinet. This interaction takes place when the player character's hands or held object reach out and overlap with the cabinet collision hotspots, triggering feedback graphics (Figure 68) that inform on player score increase and spare part placement errors, while highlighting the repair operation taking place.

Spare parts are used to expedite the process, increasing their respective repair bars to 100%. Each repair bar is accompanied by a text label referencing each part, alongside an icon representing each arcade component. The power ups mirror the brawler genre game mechanic of in-game health and weapon items. They can be picked up, used for their intended purpose, and dropped. Power ups include a CRT (Cathode Ray Tube) monitor, an arcade wiring harness, an as-

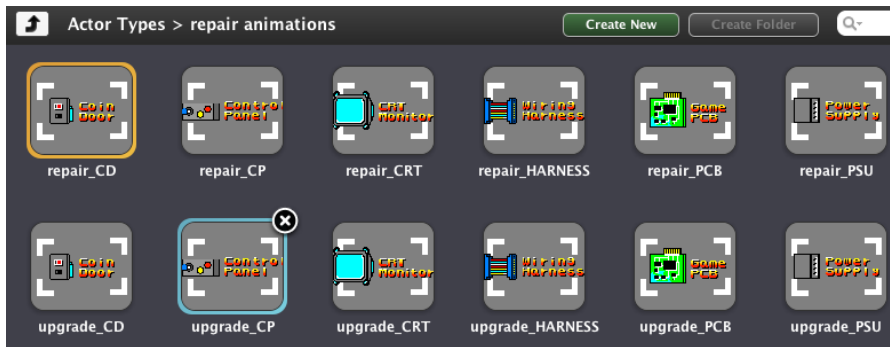


Figure 68: *Arcade Operator* repair feedback graphics.

sembled control panel, a power supply unit, a game PCB (Printed Circuit Board), and a coin-door mechanism. The spare parts are single use only, disappearing when a repair is effected. Upon completely repairing all six structural elements, the machine's artwork appears and its screen animates.

At the beginning of the demo stage, four mini cabinet icons are shown at the top left of the screen representing the number of cabinets that require repairing. Each time a cabinet is successfully repaired one icon disappears, an interface detail inspired by the hostages icons from *Shinobi* (Sega, 1987). The status icons are complimented by a horizontal bar summarising the repair bars of all on-stage arcade cabinets, conveying across the player progress at a granular scale.

#### 7.6.4 In-Game Arcade Repair

Each arcade cabinet has six components: the control panel (either joystick or steering wheel-based), power supply, wiring harness, cathode ray tube (CRT) monitor, coin-door, and the game PCB. The arcade operator uses his hands to repair each of these, but is aided in the process using spare parts found on each level.

Time and material resources are the enemies of the arcade operator as he works to fix his video game cabinets before the opening of another business day. Racing against an on-screen timer, the player character can only carry one piece of replacement hardware at a time, and although spare parts are used to expedite the repair process, placing the wrong part in the wrong place will register damage. For example, placing the coin-door into a cabinets screen region registers damage on the monitor repair bar.



## 7.7 ALTERNATIVE PRODUCTION APPROACHES

In hindsight there are alternative design decisions that could possibly have cut down the amount of build time involved to complete a fully functioning artefact. For example the using the *OpenBOR* engine would have negated the need to build a fighting game framework to fit the game narrative into. *OpenBOR* is the open source continuation of *Beats of Rage* (2003), a fully customisable side scrolling arcade brawler engine capable of publishing across multiple platforms including DOS, Windows, OSX, Linux, and DreamCast [33]. Combining *OpenBOR* with modified graphical assets from a commercially released arcade title would have reframed the project into game art, a piece of art built from the materials of existing videogame code and assets, rather than an art game, a concept game built from the ground up.

Using this approach would have presented different technical challenges and left its own unique impression on the final aesthetic, but was ultimately not implemented in favour of a bespoke build leveraging upon the author's familiarity with Stencyl toolkit from the process of designing *Control*.

## 7.8 CONCLUSIONS

During the initial research stages of this project it became clear that even though the underlying computational technologies of arcade systems remain largely as black box closed off systems at the consumer level layer, arcade cabinets of the 1980s and 1990s were predominately technically transparent systems for arcade operators, albeit demanding high competency levels in electronics maintenance. Once sold to the arcade operator, full autonomy in maintenance and upkeep of hardware was given to the customer. Arcade manuals of the 1980s and 1990s contained detailed electronic schematics and parts lists, offering full transparency for every aspect of the electronic, mechanical, and physical build of the coin-op system. The only exception to this is the software contained on the game PCB, which remained sealed off.

Like Atari's field operations manual suggests, *Arcade Operator* doesn't claim to make the player a professional engineer or technician, but aims to provide players a basic familiarity with the role of the arcade operator and basic terminology of arcade repair and maintenance.

While design processes were used to produce *Arcade Operator*, the result is not a solution to a problem, but rather an opportunity to



pose questions regarding video game genres, interfaces, and player contexts: can the arcade gameplay interface experientially articulate the non-gameplay side of interfacing with arcade technology?

Specifically, how can the arcade brawler mechanic and its diegetic environment act as an abstracted pseudo-simulator, balancing arcade play and operator-interface contexts?



## ARTEFACT C: VR SUPERGUN

This chapter details the design and development of an experimental prototype enabling play of original arcade hardware in a networked virtual reality environment. *VR SuperGun* extends the format of the standard SuperGun (see [Chapter 4](#)), a device that contains the wiring of an arcade cabinet in consolised form.

The system can also be modified to fit inside a full size arcade game cabinet, with a pass through connector leaving normal player access to the game coin-op unimpeded. *VR SuperGun* augments the arcade system's visual display, rerouting the direct feed from the arcade PCB's visual and audio outputs to the virtual display of a virtual reality arcade cabinet. ([Figure 69](#)).

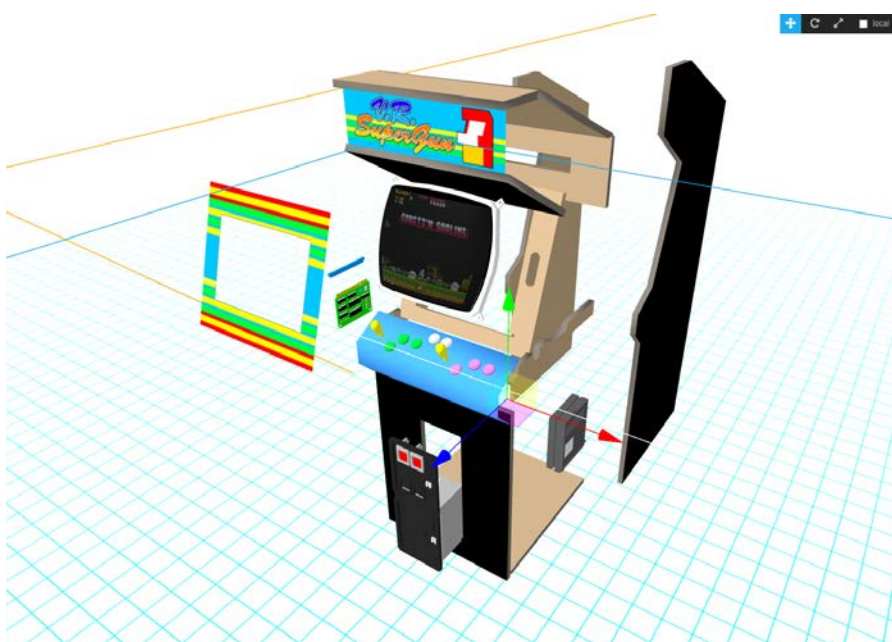


Figure 69: *SuperGun* VR prototype in exploded view mode displaying Capcom's *Ghosts 'N Goblins* (1985).

This virtual arcade shell visually recreates the presence of a full size arcade cabinet in interactive 3D space, including its internal design and electronics. In addition to playing the game presented, the user can inspect the cabinet and its surroundings ([Figure 70](#)), while accessing the technical specifications and history of the game and cabinet.

The network aspect of the *VR SuperGun* prototype, *JAMMA*node, extends access to the attached game board to remote participants, facilitating long-distance cooperative play, causing no damage to the arcade cabinet's physical enclosure. By freeing up vintage arcade machines from physical wear and tear, *VR SuperGun* offers a solution to curators and archivists seeking to allow playable access to cordoned off arcade exhibits.

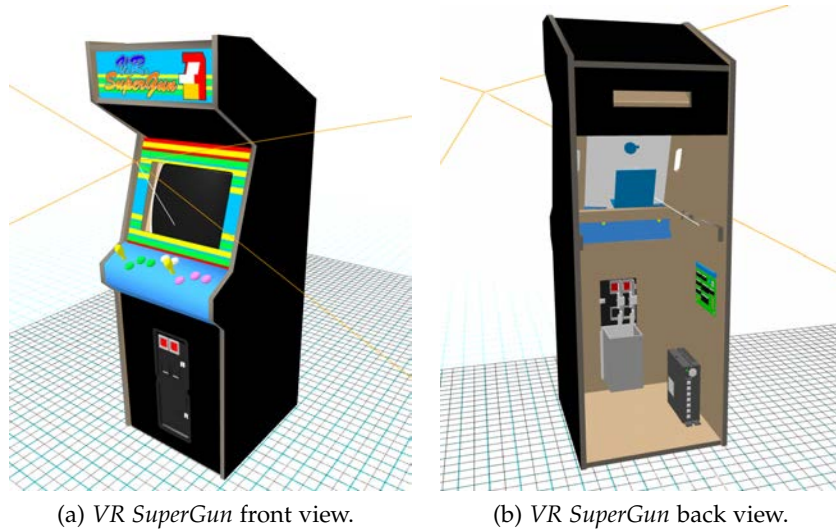


Figure 70: *VR SuperGun* front and back assembled views.

As an experimental prototype, *VR SuperGun* attempts to bridge the gap in-between the authenticity and tangibility of experiencing arcade gameplay through original hardware and in the situated space around the arcade cabinet, netplay, and the gameplay spectatorship afforded through livestreaming.

## 8.1 THE PHYSIOLOGY OF AN ARCADE CABINET

In comparison to their home computers and videogame consoles, the underlying technology powering arcade videogame platforms is lesser known. Each arcade PCB is a standalone computer. These devices range from bespoke PCBs for single games such as *Pong* (Atari, 1972), to standards built upon home console technologies like the Sega Naomi which is closely related to the Sega Dreamcast console, to adapted PC compatible machines.

Structurally arcade cabinets are unglamorous, built from the same materials as their kitchenware namesakes. Indeed, Atari's Irish coin-op manufacturing operation established in the 1970s bought a local furniture manufacturer to produce arcade cabinets for the European

market [121]. Even though Atari Ireland did not design the software for the game cabinets manufactured and distributed from its local hub, it did localise Atari's arcade machines, shaping their interactivity from an exterior environmental point of view (Appendix B). Wear and tear on these wooden frames in the arcade environment has led to high collectors prices for well-preserved originals. This battle damage adds character, but is also a problem for their upkeep and preservation, with damage including rust, chipped fibreboard, and damaged side panel artwork each demanding their own specific maintenance treatments.

An arcade cabinet is a host shell for the game logic contained on the arcade board, and in many cases the design of this enclosure adds an additional level of atmosphere and immersion to the game that is difficult to recreate outside of its natural environment. At the most basic level, these enhancements typically amount to cabinet artwork and an illuminated title marquee that seek to sell the game narrative to prospective punters. At the high end of the market arcade games begin to merge with the simulation field, adding enhancements including hydraulics and force feedback.

## 8.2 EMULATION AS PLATFORM AUGMENTATION

An emulator is a software or hardware system that recreates the system architecture of a computer system on another platform. Through the virtual machine of an emulator it is possible to experience a computer system transplanted as a subroutine of a more advanced platform, whether it be hardware-based or software-based.

Emulation is a legal grey area, and is tolerated to an extent by the owners of the emulated system. Upon boot up MAME (Multiple Arcade Machine Emulator) [107, p. 134] presents a splash screen reminding the user that they must legitimately own a copy of the game ROM they are about to load. In practice however, most users don't actually own the rare and costly game PCBs that physically contain the game code. Instead they simply use an online search engine to obtain the required ROM files illicitly.

Emulators replicate the functionality of a past platform while also leveraging the additional affordances offered by the emulation host. For example, MAME features a memory editor and disassembler allowing users to edit a games code as it runs, viewing changes of the end user experience immediately. In this case the emulator takes a system that was designed purely for the 'play only' consumer space and augments it with a developer level interface. With the additional

use of an assembler package and an EPROM burner, it is possible to transfer this new code creation to an EPROM chip, and in turn to an arcade PCB, thus allowing the hacked game to be played through the original arcade hardware platform.

When a game originally designed for playback on a cathode ray tube display is presented through the clear viewfield of an LCD or LED display, it gains pixel sharp clarity, but also loses part of the original monitor colourisation that was taken into consideration by game designers. The CRT filter built into the Atari 2600 emulator Stella addresses this issue, allowing for image ghosting and colour mixing that helps to partially mask the systems high level of sprite flickering. At hardware level, the SLG-1000 hardware device by Arcade Forge recreates the scanlines of bulky CRT tubes on flat panel HD displays, improving aesthetic authenticity when playing classic games by embracing an outdated display limitation into an essential feature.

### 8.3 ARCADE MATERIALITY IN NEW MEDIA ART

In a new media art context *VR SuperGun* offers a new conceptual angle addressing the tangibility and physicality of interaction with physical arcade cabinets. The following selection of arcade game-based artworks are pre-existing exemplars of arcade cabinets as critical artefacts.

#### 8.3.1 *OutRun*

*OutRun* by Garnet Hertz (2010) takes the deluxe sit down version of Yu Suzuki's classic coin-op and converts it into a drivable vehicle, where the videoscreen becomes a 'de-simulation' of the real world [74]. The car's screen presents a live rendering of the local map matching the original *OutRun*'s visual aesthetic. A custom computer vision application estimates the car's position on the 8-bit style map. The Ferrari themed screen bezel masks off the driver's view from their real world surroundings, placing the driver in dependence of the computer system in order to safely navigate the terrain.

#### 8.3.2 *Colorless, Odorless and Tasteless*

*Colorless, Odorless and Tasteless* (2011) by Eva and Franco Mattes is a modified 1983 *Atari Pole Position II* arcade machine [119]. The stand up driving game is fitted with an engine that revs each time the accelerator is pushed, filling the room with toxic carbon monoxide. While augmenting the videogame with authentically loud engine feedback,

it demonstrates the divide between the sanitised screen enclosed world of videogames and the visceral risks of their real world bases, suggesting there are good reasons to keep the divide between both extremes clear.

### 8.3.3 *Protopixel HARDcade*

The PC to JAMMA powered *Protopixel HARDcade* (2006) by Paolo Branca takes the physicality of the arcade cabinet as a control and audiovisual feedback unit and reconfigures it as an interface for live VJ visualisation [25]. As its players manipulate low fidelity pixel art visuals displayed through the 15kHz grain of CRT through the coin-op control panel, the PC to JAMMA system's animations are simultaneously projected at large scale for the audience, alongside accompanying reactive chiptune audio. *Protopixel HARDcade* takes the crowd spectatorship aspect of arcade gaming interaction and amplifies it as a large scale audiovisual performance.

### 8.3.4 *Arcade Concrete*

Antonin Fourneau's *Arcade Concrete* (2013) is a public space installation that presents a solution to the impermanences of coin-op physicality. A playable arcade machine in masonry form constructed from sheets of solid cast concrete, it brings arcade interaction to the streets, presenting an alternative to smart-phone format game engagement [61]. Alongside Gijs Gieskes' 2006 *Gameboy Brick* series [66], it fossilises the external form of the born-digital in a pre-digital material, for an existence stretching beyond its functional life as an electronic media artefact.

## 8.4 ARCADE MATERIALITY IN DIGITAL GAME SPACE

The representation of arcade game cabinets inside videogame worlds and emulation platforms typically takes three forms:

1. As part of geographic interface spaces styled on real world style locations where each arcade cabinet functions as a portal to game experiences separate from the main game environment. The virtual game cabinets can be tied into the narrative [181] (*Shenmue*) or function as an external menu system (*Namco Museum Volume 1*).
2. In-world virtual coin-ops for sub-games played without leaving the diegetic game space (*New Retro Arcade*, *EmuVR*).



3. As view field enhancements without belonging to an outside game environment, focusing mainly on the immediate area of the arcade monitor (Custom MAME themes, *Sega 3D Classics*)

#### 8.4.1 *Namco Museum Volume 1*

*Namco Museum Volume 1* presents a navigable virtual museum space as the main interface, but also provides an optional 2D selection menu for expediency. Released for the Sony PlayStation, the environment is distinctly low-resolution 3D, but still embodies a relatable representation of a museum style space, complete with glass cases (Figure 71), information kiosks, and a robot curator who greets you at the entrance. The main game selection interface takes the form of a high walled, column lined atrium, where doorways to each game title are arranged in a circle under a glass domed ceiling.



Figure 71: The exhibition room for *Bosconian* (left) and the atrium room (right) in *Namco Museum Volume 1* (Namco, 1996).

Each featured game has its own exhibition hall, that includes virtual exhibits including the arcade artwork, promotional pamphlets, the game PCB (Figure 72a), and gameplay tips. Each of these items can be examined in further detail. For example, on selecting the *Galaga* game PCB the user is presented with a more detailed digital photograph (Figure 72b). While the PlayStation's resolution causes significant quality reductions, the combination of low poly model and still digital photograph brings across the game board's tangibility.

The compilation also features themed rooms for each game containing virtual representation of their original arcade cabinets. *Galaga*'s room is presented in the style of a starship bridge, accompanied by a rousing orchestral rendition of the *Galaga* main score. The arcade cabinet is centre stage (Figure 72c), a portal to an emulated version of the game. Before accessing the emulator, the user can access their memory card, configure controls, and also adjust the game's difficulty using virtual PCB dip switches (Figure 72d), allowing access to an op-



erator level (see [Chapter 3](#)) of interfacing with the game board.

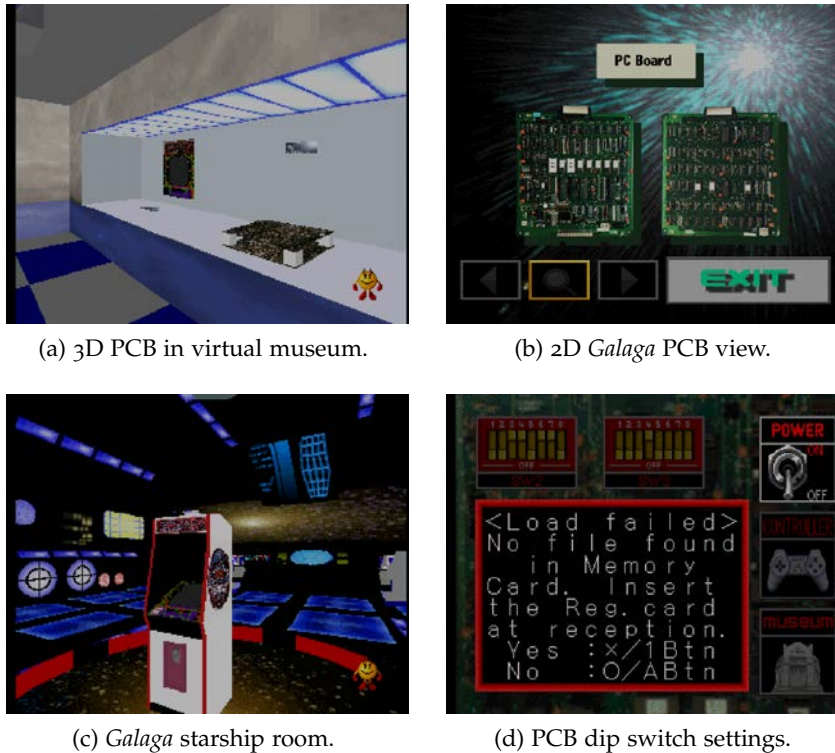


Figure 72: *Galaga* in *Namco Museum Volume 1*.

Despite the low resolution of the hard polygon aesthetic, Namco's attention to detail in creating the ambience of a videogame history exhibit communicates across a sense of respect and reflection on the creative and technical breakthroughs of each title, presenting a solid narrative of the historic significance of Namco's arcade classics.

#### 8.4.2 *Shenmue's You Arcade*

The You Arcade ([Figure 73a](#)) featured in the pioneering 3D sandbox game *Shenmue* (1999) acts as a time capsule of Sega coin-op history, featuring detailed 3D recreations of Yu Suzuki's deluxe arcade cabinets including *Hang On* (1985) and *Space Harrier* (1985) [72]. Players can walk their avatar around the virtual space to inspect the design and artwork of the arcade cabinets from different angles ([Figure 73b](#)), all while sampling the ambience of a 1980s Japanese arcade amusement centre.

Unlike *Namco Museum's* use of an environmental interface as an initial menu system, *Shenmue's* virtual arcade space isn't immediately accessible, playing a small portion of a larger narrative. In-world time

and distance also factor it's accessibility, as the arcade only opens between 10am and midnight, with ten minutes in the *Shenmue* universe equivalent to one hour of actual time.

Upon starting each virtual arcade game, the viewpoint switches from third person perspective to completely replace the playfield with the arcade monitor view. The design decision is a necessity due to the DreamCast console's hardware constraints. However directly separating the diegetic spaces of the main game environment and the sub games also serves to appropriately differentiate their contained worlds.



(a) Outside *Shenmue*'s You Arcade. (b) A *Space Harrier* cabinet in *Shenmue*.

Figure 73: Outside and interior views of *Shenmue*'s You Arcade.

#### 8.4.3 *New Retro Arcade: Neon*

MAME plays an essential role in videogame preservation despite concerns over the copyright status of ROMs used [128], *New Retro Arcade: Neon* extends MAME as a preservation tool, presenting a reconstituted, if idealised, virtualisation of the memory of the situated play environments of arcade videogames from the 1980s and 1990s.

*New Retro Arcade: Neon* (2015) by Digital Cybercherries presents a richly detailed virtual recreation of an arcade amusement hall as a front end for MAME (*Multiple Arcade Machine Emulator*) [31]. The application latches onto the memory of 1980s and 1990s arcade videogame spaces, using a vaporwave-inspired, neon-infused graphical style. By presenting AAA level physical representations of each arcade ROM in the users collection as a virtual arcade cabinet, it provides a tangible visual reference of each game title as they were experienced in their original hardware form (Figure 75a).

#### 8.4.4 *EmuVR*

The in-development *EmuVR* [54] enhances the virtual game room concept of *New Retro Arcade: Neon* through further levels of environmental interaction. *EmuVR* allows users to experience their collection of classic game ROMs through 3D representations of classic gaming hardware. Instead of an amusement arcade, *EmuVR*'s space is in domestic setting, containing game consoles dating from the 1980s to early 2000s. As with *New Retro Arcade*, *EmuVR* is aimed at game collectors, and contains recreations of non-digital videogame paratextual elements such as game packaging and videogame magazines to amplify the nostalgic impact of the environment and provide further context.

Further interaction rituals introduced by *EmuVR* include powering up game hardware, inserting game cartridges into game consoles, and connecting the console to a television set (Figure 75b). *EmuVR* also supports passing of the virtual gamepad between players when taking turns during multiplayer games. In this instance, accessibility is traded for awkwardness for the sake of nostalgia, but also the proximity of local multiplayer gaming.



(a) *New Retro Arcade: Neon* virtual environment.



(b) Connecting the virtual representations of a PlayStation and N64 to a pair of televisions in *EmuVR* (2018).

Figure 74: The VR environments of emulator front ends *New Retro Arcade: Neon* and *EmuVR*.

### 8.5 FRAMING THE 4:3 ASPECT RATIO: PERIPHERAL VISION

In order to fit the 4:3 aspect ratio of a JAMMA compliant arcade game to modern widescreen formats without modifying its aspect ratio or screen layout, it's necessary to frame the emulator image in a border. The default option is to leave this blank, however the opportunity to customise this area of the visual interface provides room to reconsti-

tute the immediate space surround the arcade screen by reconstructing the bezel and marquee artwork, increase the sense of immersion and atmosphere.

#### 8.5.1 *Sega 3D Classics*

*Sega 3D Classics Collection* (2015) presents a handheld specific take on reconstituting the physical form of arcade game cabinets in digital space, tailor made for the Nintendo 3DS. The compilation's game selection screen displays rotating low-polygon 3D versions of the exterior form of several Sega coin-ops including *Power Drift* (1988), *Thunder-Blade* (1987), and *Galaxy Force II* (1998). Upon selecting a title, a first person perspective viewfield of the arcade display is surrounded by a periphery view of the cabinet. Selected titles on the compilation including *Thunder Blade* (Figure 75) harness the system's gyroscope, realigning the onscreen game's peripheral viewfield when the device is tilted [1].

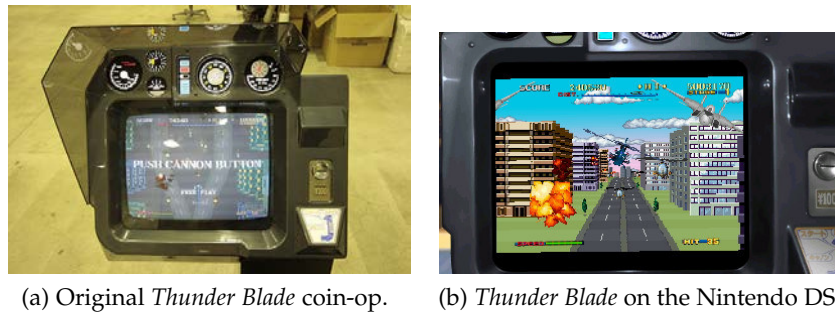


Figure 75: *Thunder Blade* (Sega, 1987) as a custom arcade cabinet (left) and on Nintendo 3DS (right) as part of *Sega 3D Classics* (Sega, 2015).

#### 8.5.2 *Custom MAME themes*

MAME supports the use of HLSL (high-level shader language) filters [168]. While shaders are most commonly associated with 3D graphics rendering, they are also applicable to 2D images on a pixel by pixel level.

Flinnster's virtual arcade cabinet design for *Wonderboy* (Sega, 1986) provides an exemplar of how HLSL effects can create a vintage arcade visual aesthetic [60]. The modification applies scanlines, bloom (the bleeding of bright colours into neighbouring pixels), and stretches the game display horizontally (Figure 76).

The 4:3 aspect ratio of the game display is surrounded by custom marquee and bezel designs that fill out the remainder of the widescreen viewfield. These are not exact replicas of the original *Wonderboy* cabinet art but a composite built from various media related to the title. By combining HLSL filters with bezel and marquee art, Flinnster's work demonstrates how the clinical pixel sharp default of modern emulation can mimic the image distortions of faulty cathode ray tube screens.

"My aim is to recreate what I remember it feeling like to play my old favourites in the flesh – but where the real artwork was poor or non-existent, to create it in a way that feels authentic and slightly modern, as if the art and game was being made today. I finish off with dirt and small bits of damage, to age the 'cabinet' as if it was genuinely a 'collectors' machine that had been released 30 years ago, and has signs of age and wear" [60].

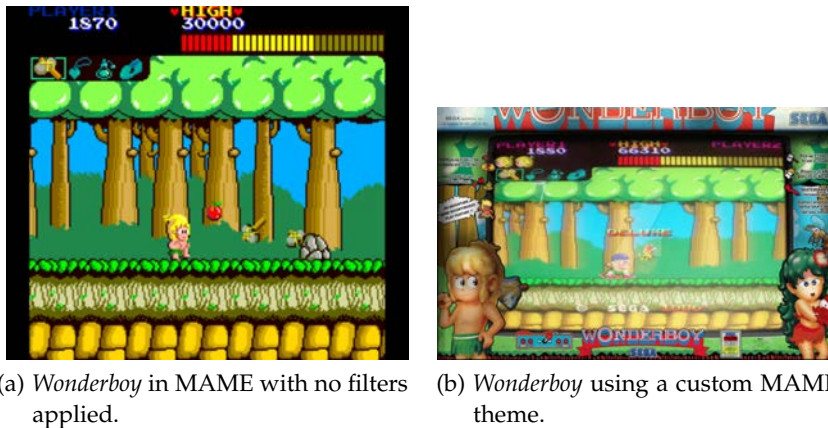


Figure 76: Comparison between Wonderboy on MAME with no filters applied (left) and using Flinnster's custom MAME theme (right).

## 8.6 INTERFACE DISTANCE AND RITUAL

The distance between the swiftness in execution of a command line instruction and the movement and gestures of a mouse click or touch-screen swipe are made as a compromise to greater accessibility. While a command line instruction is the most efficient route to executing a function, it requires memorisation and technical knowledge of the host platform. The desktop metaphor, in both its traditional point and click form, and as adapted for mobile touchscreen use, leverages users' prior knowledge through icon-based metaphors, and where direct communication is necessary uses unabstracted imagery.



Walking through virtual spaces, without the use of teleports or shortcuts, exists at the extreme end of long windedness in interface navigation. Joseph Delappe's 2008 *The Salt Satyagraha Online* [45] provides an extreme example of the time investment involved in navigating virtual space. In this game art performance the artist walked 240 miles over 26 days through the landscape of Second Life, the motion of the Gandhi avatar linked directly to the movement of Delappe on a modified treadmill (Figure 77).



Figure 77: Joseph Delappe's reenactment of Gandhi's Salt March in *Second Life* (2008). Photo credit Laurie Macfee: <https://flic.kr/p/4H94xu>

#### 8.6.1 Environmental Interaction Memories

In Masamune Shirow's *Ghost in the Shell*, cyborgs eat fake food to satisfy a memory, while facilitating the humanity of mealtimes as a social ritual [91]. The visual and olfactory aesthetics of the culinary experience proving more powerful than any machine logic that would rule out nutritionless eating as inefficient.

So too appending operationally extraneous functions to an interactive experience may seem unnecessarily long winded from a usability point of view, but serves the purpose of delivering a background narrative from within the diegetic space of the virtual space and the nature of interaction within it. Environmentally-based interfaces trade navigational efficiency for the familiarity of real world navigation cues, allowing a more naturalised user experience.

Manovich (2014) describes new media interfaces as representations that "privilege particular models of the world and of the human subject" [116, pp. 41-42]. Virtualised representations of videogame play spaces serve up environmental interface models targeted at both the memory of veteran game players and also romanticised ideals as embodied in the neo retro and vaporwave aesthetics.

Environmentally-based interfaces set in retro game culture themed virtual spaces trade navigational efficiency for the familiarity of real

world navigation cues, allowing a more naturalised user experience while tapping into and augmenting past memories.

### 8.7 DIGITAL PRESERVATION: FUNCTIONALITY VS. AESTHETICS

The exhibition 'Pong to Pokemon: The evolution of electronic gaming' at Bullock State Texas History Museum in 2017 presented a 1978 Midway *Space Invaders* cabinet to the public behind a glass shell (Figure 78a). This image is striking, as it presents a scenario where the materiality of classic arcade hardware is off limits to museum visitors, who become spectators, experiencing visually rather than experientially. In this inert non-interactive state the coin-op becomes what Guins refers to as an ex-game [71, p. 13]. The aura of the real that Benjamin refers to is present [20, p. 10], but without the added dimension of linking to the world inside the cabinet.

The issues faced by museums and art galleries due to impervious materials in artworks deteriorating over time apply to video game preservation. The phenomenon of bit rot [131, p. 11], the physical decay of magnetic media, and the breakdown of plastics in computer and game console casings are targets for remedial action by the preservation and media archeology fields.

In 2014 a team led by media artist Cory Arcangel assisted the Andy Warhol Archives in rescuing collection of previously unviewed images created by Warhol in Commodore Amiga floppy disc format. This preservation task was achieved using proprietary software and hardware to rescue recover data from faulty discs [162].

In order to present the media to the public over a long term duration, Iontank retrofitted a series of Amiga 1000 computers with solid state PC hardware running custom Amiga emulators, under the logic that the PC components are running under warranty, and are easily repairable [80].

The decision was also made to remove the glass tube from original Amiga monitors and fit flat screens inside the original frames. The look and feel of the Amiga 1000 display is closely approximated through a custom milled lens superimposed onto the flat screen display. By using this combination alongside a scanline filter, the original cathode ray tube monitor's signature curve is reproduced. Floppy loading times are kept in line with the original platform, while the original keyboard mouse, and system indicator LEDs remain functional (Figure 78b).

Iontank's Amiga 1000 reconstruction provides an exemplar in balancing practical considerations regarding the maintenance and upkeep of a decades old legacy computer system, while maintaining an era-authentic aesthetic alongside continuity with the original platform's visual, audio, and interaction capabilities.



(a) *Space Invaders* behind glass.  
Image © 512tech.com.



(b) Reconstructed Amiga 1000.  
Image © iontank.com.

Figure 78: *Space Invaders* and Amiga 1000 preservation examples.

#### 8.7.1 ROM Materiality

The programs contained on arcade game boards holds physicality not just when compiled and run as game worlds, but also in their raw, un-executed form. MAME is open source software, a community effort under constant development, pooling together diverse stakeholders in the arcade preservation community including collectors, programmers, and designers. This power in numbers is also harnessed to reduce time on the meticulous and lengthy task of transcribing and reverse engineering the contents of copy protected custom chips.

The CAPSoff initiative [32], in operation since 2016, is one such effort dedicated to cracking and replicating arcade security chips. The process involves removing the the top layers of the chips using nitric acid and acetone. When the decapped ROM chips are photographed under a microscope and magnified 100x the binary code becomes visible, and can be transcribed. In 2017 CAPSoff crowdsourced the transcription of Fujitsu manufactured security chips for Sega's *Virtua Racing* (1992).

The chip photograph was divided into portions, each representing an 8 x 8 grid of binary memory storage, with a computer vision algorithm used to render the 1s and 0s as high contrast light and dark squares. Each portion was shared online, inviting volunteers to enter to their transcription of the grid into a text form. All the individual transcriptions are then combined into a composite view that is then



rendered as executable code. The first chip from the set was successfully transcribed by 88 volunteers of 15 days [137].

This crowdsourcing of a mammoth task divided into small parts parallels Google's reCAPTCHA book transcription feature, and Aaron Koblin's 10,000 contribution art piece *The Sheep Market*<sup>12</sup> [36, pp. 280-281], albeit in an unpaid capacity. CAPSoff and their peers work also highlights the tangibility of digital information, rendering encoded arcade ROM binary as human readable visible blocks, their materiality made accessible and thus replicable, modifiable, and emulation ready.

<sup>12</sup> 10,000 volunteers collaborated to create a visual art montage of left facing sheep for \$0.02 each.

### 8.7.2 Emulation and Tangibility

As arcade games move from public play space into private collections for preservation and archival purposes, opportunities to engage with the original platforms lessen. Arcade genre games experienced through home computer and console ports, conversions, and emulators trade-off the tangibility of classic computational platforms against the accessibility and convenience of gameplay untethered to the material constraints of the original system. The user of an emulator receives ease of use and new non-diegetic operator acts such as a pause function [63, p. 13] while sacrificing constraints that defined the nature of the original system.

In the case of an emulation platform that perfectly reproduces the sonic and visual properties of the legacy system to the end user, the underlying computational technology is still removed from the original platform.

For the user with first hand memory of using a classic videogame, their memory fills in the gaps of imperfection in the user experience when using emulation. Similarly, a lack of linkage to the source experience creates a new situation, one with no first hand memory of the referenced experience, but influenced by second hand memories in the media and popular culture. The gaps in comparison between the analog and digital versions of the given experience are less obvious to this target audience, leading to the flaws in resolution becoming features. We can see this in the use of pixel sharp imagery from the 8-bit era. The sharp right angles of pixel art in its post digital context contradict the blurry phosphor tinged images viewed by gamers during the early years of videogaming, yet are accepted as authentic by the 8-bit revival audience.

The tangibility of real game hardware and software can also be seen as subjective to the user, a tangible link with past memories, design and manufacturing origins of the medium, or indeed a badge of honour of belonging to an exclusive tribe of arcade collectors and appreciators.

## 8.8 HARDWARE AND SOFTWARE DEVELOPMENT PROCESS

The hardware design and codebase for this artefact was developed using open source and web standards where possible. This approach allowed a modular and adaptable development path. By using browser-based WebVR, the *VR SuperGun* platform can take advantage of ongoing developments of the A-Frame platform [3], including support for augmented reality and mixed reality, while remaining accessible and platform agnostic.

The build process of the *VR SuperGun* prototype went through several iterative stages. Since remote game streaming and control forms the backbone of this experience, highest priority was given to delivering low latency for both the video feed and player inputs. The 15kHz, 240p RGB signal from the arcade PCB was fed through an OSSC 2<sup>13</sup> upscaler, upsampling the video resolution from 15.5kHz 261p RGB to 720 x 480 at 60 frames per second. This HDMI image was then fed into a USB3 AVerMedia LGX Extreme 550c Game Capture unit, supplying a zero latency USB signal to the PC. However this signal couldn't be presented as a web browser ready stream until it was transcoded. As *VR SuperGun* is built upon web technologies, the HLS web streaming protocol was tested to stream HTML5 video directly into the browser from an attached game capture card.

<sup>13</sup> *Open Source Scale Convertor, a hardware device enabling conversion and upscaling of legacy video formats to HD.*

Initially the HLS stream from the capture unit was tested with a custom NGINX server, and then with Unreal Media Server. Both tests yielded latency of between 3 and 8 seconds, which is suitable for livestreaming directed at a view only audience, but unworkable for direct interaction. Direct HLS streaming from a capture unit feed sent to VLC player was also tested, but also resulted in high latency unusable for instantaneous gameplay.

A workaround to the latency issue was found while exploring the affordances of the A-Frame WebVR platform. In addition to the use of imported 3D objects and textures, A-Frame allows use of HTML canvas images as textures on pre-defined geometries such as planes and cubes. The possibilities for replacing this static texture with a constantly updated texture was made possible by combining an open source code sample for streaming FFMpeg to the HTML canvas with

A-Frame's own canvas texture functionality. FFMpeg is a versatile command line media transcoding tool, the Swiss army knife of video conversion, and can process audio and video from multiple input formats, including video capture card streams. The incoming 720 x 480, 60 frames per second HDMI signal was downsampled to a 360 x 240 resolution, 500kbps bandwidth stream at 23.98 frames per second.

The custom FFMpeg to HTML canvas texture solution resulted in a lag of 0.3 milliseconds on a 4GB 1.92 GHz setup (Figure 79), with improved results of between 0.11 and 0.17 latency on an 8GB 2.5 GHz powered quad core PC. The trade-off for the canvas streaming method is that sound is not supported, and so is routed through a direct wired connection to speakers on the prototype unit.

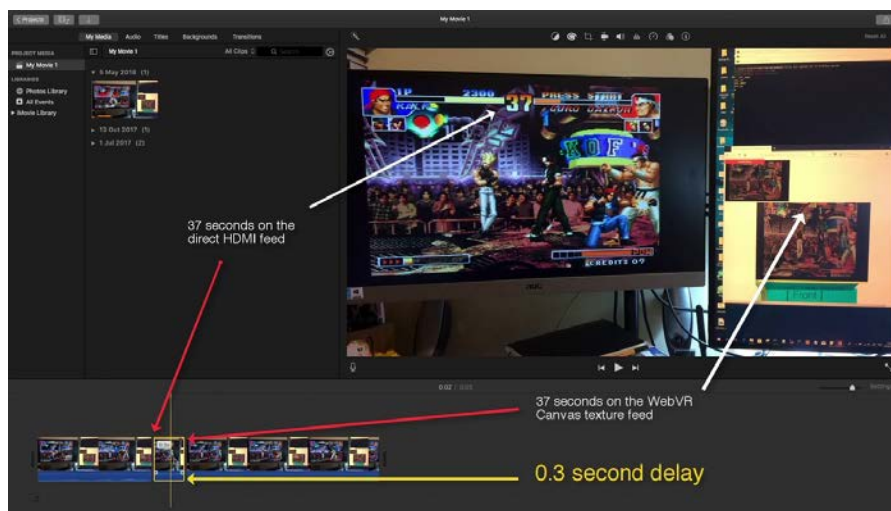


Figure 79: VR SuperGun Latency Test A.

### 8.8.1 Modular Code through Web Frameworks

Using web frameworks allowed the VR SuperGun build to proceed in an extendible, modular fashion, and also naturally lent itself to facilitating online connectivity.

All JavaScript libraries used were backed up from their respective remote hosts and run from a local install, enabling offline use, while negating the risk of their source repositories being deleted.

### 8.8.2 Browser to JAMMA Hardware Interface

In order to physically control the 26 inputs on a standard 2 player JAMMA board from a PC web browser, a custom adaptor was built

using an Arduino MEGA running Firmata (Figure 80). Phaser.io was used to read the game control keypresses from the browser. The code was set up to detect key down and key up states for each input, while ensuring there was no repeat signal when the key is held down. The Socket.io and Johnny-Five javascript libraries were used to make the connection between the browser and the Arduino.

The Arduino's digital IO pin output signals were fed through an array of 26 optocouplers on a breadboard circuit. Each optocoupler is a digital switch that in turn triggers a corresponding input on an ArcadeForge JAMMAhelper board (Figure 81). This solution is distinct from existing Arduino to JAMMA circuits such as the JAMMArduino as its pass through adaptor allows the host JAMMA wiring harness to continue supplying power to the board, while retaining access to the board's control and audio-visual signals.

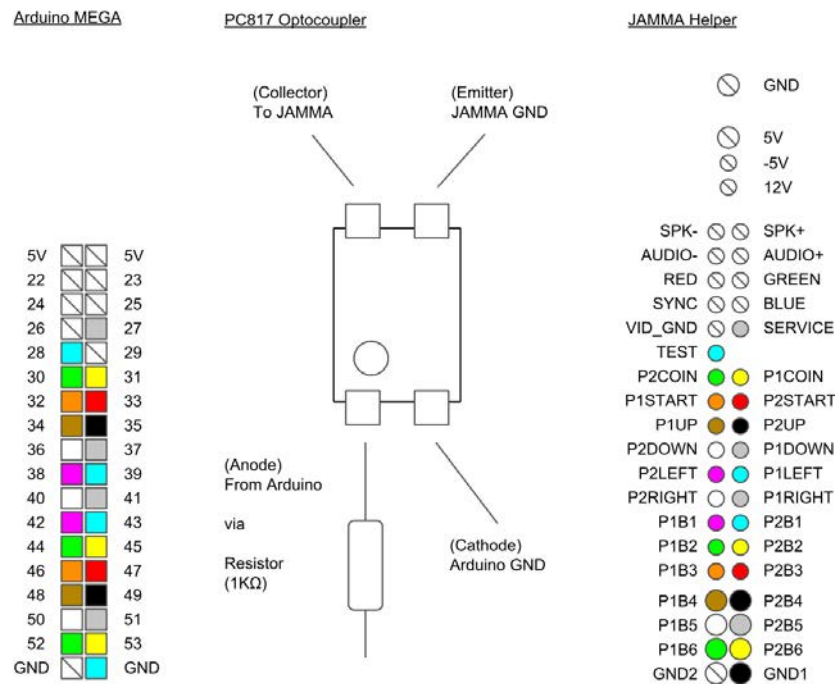


Figure 80: Wiring diagram for Arduino MEGA to JAMMAhelper custom circuit.

## 8.9 VIRTUAL ARCADE CONSTRUCTION

Milkshape 3D was used for modelling and texturing all of the VR SuperGun / JAMMAnode 3D assets. Milkshape was first released in 1996 to support creating and editing of in game assets for low poly 3D games of the era such as *Quake* (id Software, 1996), *Half Life*

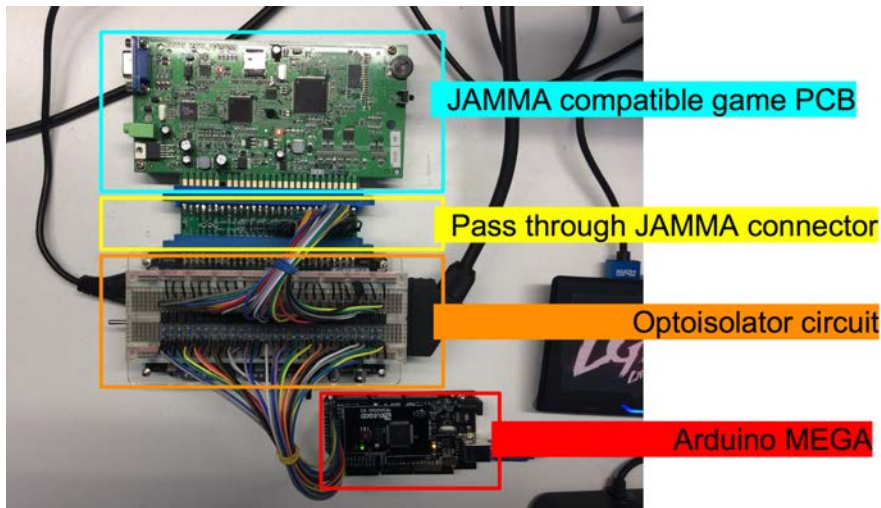


Figure 81: VR *SuperGun* control circuit.

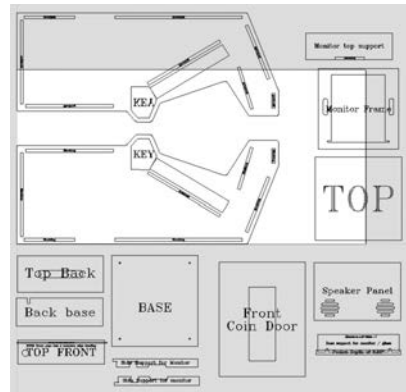
(Valve, 1998), and *The Sims* (Maxis, 2000). The hard polygon aesthetic afforded by Milkshape 3D's toolkit suited the visual constraints decided for this artefact, both to maintain a look and feel of 1980s and 1990s 3D arcade titles such as *Virtua Fighter* (Sega, 1993), and also to minimise computational resources, allowing for a smooth frame rate and a compact, portable hardware footprint.

The VR *SuperGun*'s onscreen arcade cabinet was based upon the Dynamo HS-1, and modelled by directly referencing CAD diagrams from the Classic Arcade Cabinets online repository [38]. The Dynamo HS-1 was a blank kit cabinet used by companies including Capcom, SNK, Technos / Romstar, and Kaneko. Each arcade manufacturer modified the design to their own specifications through a conversion kit containing game specific artwork and control panels. The HS-1 was chosen because of its association with *Street Fighter II*, a game that adapted the form of the machine through an extended control panel designed to house the six buttons per player necessary for its gameplay (see Chapter 3).

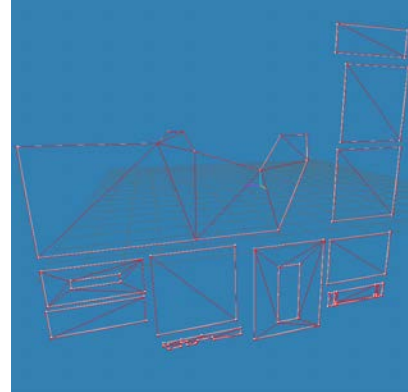
The HS-1 plans provided by Classic Arcade Cabinets are provided in CAD format ready for use in CNC wood carving machinery, and are described as 86% accurate (Figure 82a). The bitmap preview of the HS-1 schematics was traced vertex by vertex as low triangle models in Milkshape 3D (Figure 82b), with the textures edited in Adobe Photoshop and then mapped to the panels (Figure 82c). Each panel of the virtual arcade cabinet was built as a separate .obj model, then imported into an A-Frame document where the digital HS-1 was assembled in A-Frame's inspector view (Figure 82d) by referencing the guide photographs from the Classic Arcade Cabinets site, no nails or glue required. Once all elements were positioned in place, their co-



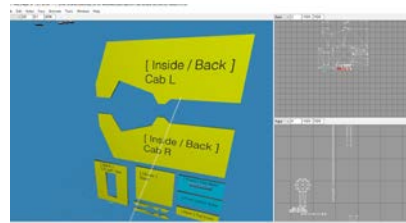
ordinates were exported from the A-Frame inspector clipboard and hard coded into the main HTML file.



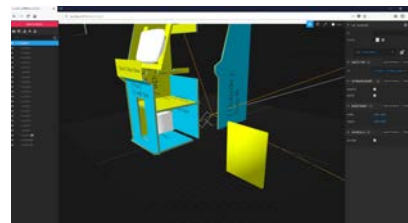
(a) Dynamo HS-1 schematics.



(b) Vertex modelling in Milkshape 3D.



(c) Texture mapping in Milkshape 3D.



(d) Assembling the HS-1 in A-Frame.

Figure 82: Modelling and assembling the virtual arcade cabinet.

### 8.9.1 Grid Environment

The *VR SuperGun*'s grid environment was generated with Don McCurdy's a-grid.js A-Frame extra [122]. It serves to visually anchor the prototype virtual cabinet in place, helping the user gauge the arcade cabinets's position in virtual space.

### 8.9.2 Virtual CRT Monitor Design Process

Modelling the CRT monitor enclosure was one of the most challenging aspects of this artefact build. The canvas plane hosting the video stream sent from FFMpeg is a modified sphere rendered through code in A-frame, with the top, bottom, and back removed, then scaled down on the x-axis to a convex shape. To build the virtual display frame in Milkshape the convex shape was exported from A-Frame as a glTF file<sup>14</sup>. This was then imported into Blender, and exported in Milkshape ready OBJ<sup>15</sup> format to form the starting point for the full CRT frame. When the monitor was fully modelled the original convex shape that it was developed from was subtracted from it, leaving a

<sup>14</sup> GL Transmission Format, a 3D file format optimised for web delivery.

<sup>15</sup> An open and standardised 3D file format developed by Wavefront technologies.

frame. Finally the original convex object and the monitor frame were fitted together in the WebVR scene.

### 8.9.3 *Vectors to Voxels*

In the later stages of the build the voxel modelling application MagicaVoxel was used to model the power supply unit, PCB, JAMMA connector (Figure 83a), joystick bases, and coin-door mechanism. As with the Milkshape 3D authored assets, all the voxel graphics produced for the *VR SuperGun* directly referenced the Dynamo HS-1 arcade cabinet design (Figure 83b), and were imported as .obj files into the A-Frame scene.

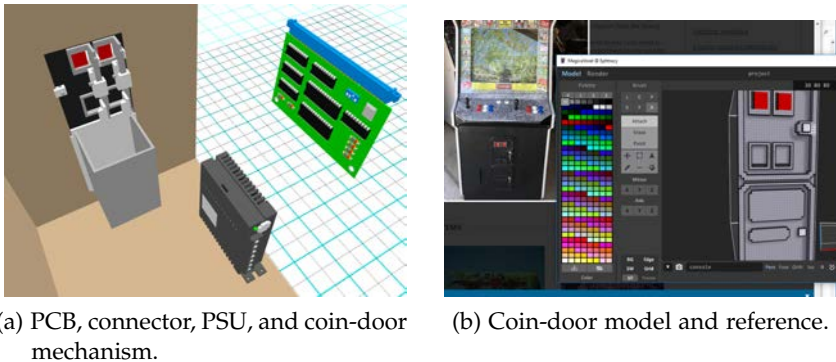


Figure 83: Voxel modelled arcade components exported as low resolution .obj files.

## 8.10 NETWORK PLAY PROTOTYPE

In addition to local play access, *VR SuperGun* allows live remote play of JAMMA compatible arcade game boards over the internet. It is unique in comparison to existing interactive streaming solutions as it uses original game hardware rather than an emulator core, and can also provide remote access to unemulated arcade hardware.

### 8.10.1 *Remote Access Implementation*

An *ngrok* [78] http tunnel proxy was used to create an ad-hoc internet presence for the *VR SuperGun*, this allowed remote browser access to the prototype's localhost folder. Separate secure SSH tunnels were implemented for the websockets connection used for serving the canvas texture stream, and also for the socket.io server enabling browser control of the physical JAMMA inputs via an Arduino MEGA enabled custom circuit. The test rig ran on a 4G connection for both upload of the local *VR SuperGun* stream and download of the remotely served



*VR SuperGun* implementation. A 0.2 second delay was recorded between the localhost stream and the ngrok served remote stream.

### 8.11 INTERACTIVE PROTOTYPE OVERVIEW

Figure 84 shows the first fully functional *SuperGun* VR prototype setup, with Figure 85 detailing the hardware connections in diagram form. The prototype is built with portability in mind, using a small form factor PC to minimise the hardware footprint, allowing the system to fit inside an existing arcade cabinet or to function as part of a desktop *SuperGun* system.

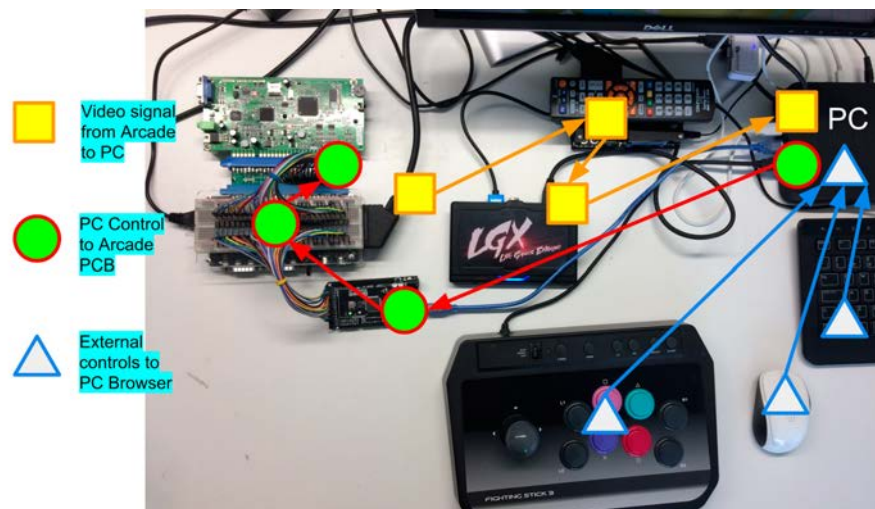
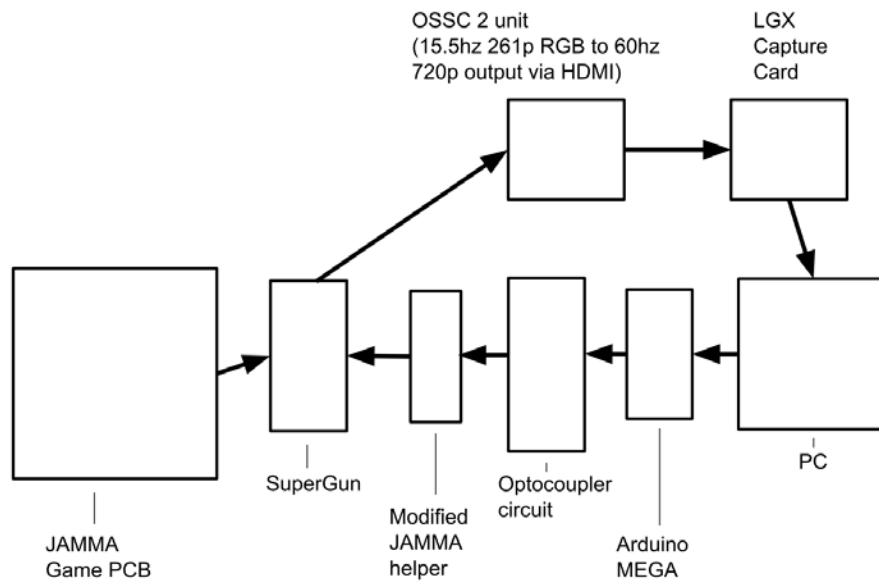


Figure 84: *VR SuperGun* desktop setup.

Upon startup, the A-Frame HTTP server runs alongside separate streaming servers for control of the JAMMA PCB pins, and also for conversion of the FFMpeg stream to HTML canvas via Javascript.

The virtual cabinet, while low resolution, maintains structural fidelity with the original physical artefact, recreating to scale the external and internal physicality of the arcade system. This internal view of the digital arcade cabinet demystifies the internal structure of the arcade machine, presenting the internal aesthetics of the wiring and circuitry as a visible and essential part of the overall cabinet build, while also providing a historical and educational document of the machine hardware that is impervious to wear and tear.

In basic flat monoscopic 3D mode, the *VR SuperGun* / *JAMMANode* environment presents the virtually recreated arcade cabinet in a blank construct with a blueprint style grid floor. The position of the view field is controlled through the WASD keys and the mouse. A further

Figure 85: VR *SuperGun* hardware diagram.

26 keyboard inputs map to the JAMMA board controls (Figure 86), and are in turn mapped to a USB arcade controller through the An-timicro keyboard mapper. The canvas video texture is mapped across a modified sphere geometry via custom javascript, approximating the screen curvature of a cathode ray tube monitor (Figure 87).



Figure 86: Key map used for browser control of the Arduino to JAMMA connection.

The VR *SuperGun* prototype provides a compromise between the immediacy and convenience of emulation and the visceral, situated experience of playing a physical arcade cabinet. It extends the JAMMA interface standard into networked 3D space.

This prototype uses A-Frame WebVR as a delivery platform, bringing network connectivity to the JAMMA arcade standard. A live video stream from the connected JAMMA game PCB is presented as the screen texture on a 3D representation of an arcade machine using, thus reconstituting the physical form of the coin-operated cabinet in the digital space of the web browser. VR *Supergun's* graphics are deliv-



Figure 87: A live feed from *Altered Beast* (Sega, 1988) streamed to the HTML Canvas. The video texture is mapped to a modified sphere on the left, and to a flat plane on the right.

ered in a low polygon style fitting a mid-1990s arcade vector graphics aesthetic. By using a WebVR enabled interface the experience is accessible from basic desktop (Figure 88) and mobile browsers as flat 3D, and also through WebVR compatible virtual reality, augmented reality, and mixed reality headsets.

#### 8.12 FUTURE DEVELOPMENT PATHS

While the *VR SuperGun* artefact exists as an early working prototype, there are a number of modifications possible in terms of both hardware and software implementation that can help improve functionality, usability, aesthetics, and overall user experience.

As mentioned in a previous section, the latency of the local video stream dropped when a higher powered PC was used, prompting an obvious path to further decrease this encoding delay through the implementation of increased hardware resources.

In user testing, the Arduino to JAMMA circuit at times fails to register keypresses due to shaky connections between the optocoupler<sup>16</sup> chips and the breadboard. Replacing this prototype with a hand soldered perfboard or more durable printed circuit board will increase stability.

<sup>16</sup> An optocoupler is an electronic switch that links two circuits optically.

Network play is currently supported through a single player ngrok testing server, and does not detect the amount of players present or



Figure 88: The VR *SuperGun* prototype set up in desktop mode using a flat monoscopic 3D display.

offer chat functionality. The addition of a front end for network play, including user log-ins and a queue system can eliminate potential multiplayer clash and contribute to the development of the platform as a space for spectating play as well as direct gameplay itself.

As the prototype is at the time of writing at early development stage, there is much scope to improve the user interface aesthetically. For example through the addition of extra arcade cabinet reproductions alongside their technical, historic, and design details. The inclusion of suitable ambient audio effects sampled from arcade amusement establishments can also lend to greater immersion and atmosphere.

Additionally, the use of photogrammetry to import museum level 3D scans of arcade machines and their environments offers the possibility to increase the applications value as a environment for the digital preservation and documentation of arcade videogame technology.

Also the inclusion of a supplementary video feed can allow remote users to see the attached board and its local environment, strengthening the connection between the player and the original host hardware.

*VR SuperGun's* internet connectivity scope to share gameplay online and build a community centred around access to rare and origi-

nal arcade PCBs. Liveplay streaming functions as a form of performative media [177] among the arcade videogaming community through platforms including Twitch and Nico Video. These services can be considered as the network age descendants of the situated communal aspect of arcade game centres.

### 8.13 CONCLUSIONS

The *VR SuperGun* offers a new conceptual take on directly interfacing with legacy arcade hardware. By connecting videogame players and original arcade systems through networked space via the aesthetic layer of low-polygon virtual reality, *VR SuperGun* strikes a balance between accessibility and preservation, enabling a compromise between authenticity and virtualisation in arcade videogame interaction.

As a media art installation *VR SuperGun* extends the material of the JAMMA hardware standard into virtual space, providing a meditation on the physicality of arcade hardware in both its corporeal form and situated environment.

The artefact also functions as a prototype solution to preserving classic arcade hardware while still allowing playable access. It is envisioned that *VR SuperGun* can allow games network access to games in both private and museum collections, allowing their use without causing physical damage to their machine exteriors, enabling rare unemulated (and unemulatable) arcade titles to reach out from private collections and cordoned off exhibitions as directly playable experiences. By doing so not only is the arcade machine virtually reconstituted in digital space, but also the communal game space of the arcade itself.

## Part IV

# CONCLUSION





## CONCLUSION

---

### 9.1 CONTRIBUTIONS

As a practice-included platform study derived approach, this thesis provides combines methodologies from art and design based research, game studies, media archaeology, and related cognant fields. By approaching its subject matter from both theory and practice angles, it presents findings into the creative process and materials of digital game platforms synthesised from a broad range of primary and secondary research sources, strengthened from first hand tacit engagement with the subject material.

#### 9.1.1 *Game Studies Contribution*

This research study of JAMMA era arcade interaction aesthetics and materiality combines several angles of inquiry, including historical, technical, and design based. As it draws from multiple disciplines, so too it feeds back to these source knowledge domains.

From a game history perspective this thesis contributes to understanding on the origins of the JAMMA standard, considering the factors that shaped its emergence, while synthesising a history of JAMMA era arcade development. The JAMMA arcade standard is considered a family of platforms when combined with compatible game boards, and a platform constrainer in its wiring harness guise. As a material and aesthetic study, this thesis aligns the artistic processes of arcade developers with the creative practices of indie developers and media artists.

In terms of developer history this thesis makes an original contribution to understanding the diversity of game development processes used to engage with the material of the arcade as platform and genre. This view of JAMMA era arcade development was formed by unearthing, collating, and analysing pre-internet age interviews with arcade conversion developers alongside insights gained from both primary and secondary sources on arcade industry creative techniques. In addition, the design implementations of modern indie arcade developers form part of this overview, unifying retro and retro inspired game aesthetics.

It presents a unified treatment of JAMMA era arcade games, broadening understanding of links between game design, technical constraints, and the methods by which creatives in the game development industry and videogame related creative subcultures engage with arcade games as creative media forms.

#### 9.1.2 *Interface Aesthetics Contribution*

This research contributes to HCI and software studies by both practically and conceptually approaching the human to computer interface of arcade videogames from media art and software studies angles. It delivers a series of critical design implementations that harness interaction aesthetics to probe the materiality of not just the human computer link in arcade gaming, but also the broader area of human computer interaction. These interactive artefacts while not initiated from a commercialised user-centric point of view, harness interface usability to experientially articulate and explore issues surrounding the limitations, context, and materiality of not only the interface in terms of onscreen and control based modalities, but also regarding the integration of the digital and physical environment layers of everyday existence.

The alternative scenarios on interaction manifested through the artistic development and implementation of the arcade meta interface trilogy serve to provoke new insights into interface materiality and aesthetics from their users. For example, the *Control* meta game prompted feedback from a medical computer human interaction researcher who suggested that the artefact's embodied hand and controller scenario could be modified into a testing ground for medical interface functionality, providing a safe training zone for electronic medical interfaces.

Accessibility and the limitations of the physical game controllers are also explored through artefact A. *Control's* control scheme is a deliberately difficult one, this is in keeping with unforgiving high difficulty arcade play, but also is a critical response to usability centred design. By embodying the user through a downsampled representation of their hand, the user is placed in a compromised position dexterity-wise. This situation is created with the aim of engendering empathy, using the interface to expose its dependence on human faculties.

This thesis also contributes a novel use of internet based user research, through the use of YouTube based game reviews as test data. A form of netnography, these video playthroughs were transcribed,

coded, and combined with additional feedback in the form of text based online reviews and first person feedback to bolster the insights gained.

Additionally, this research offers a unique series of case studies to the HCI community on the role of the environment as an interface layer in exhibition spaces as shaped by curator decisions. The *Control* artefact is compared and contrasted in various incarnations across five exhibitions, with each installation design shaping public experience of the core artefact's interaction aesthetic.

The contextual layer of the interface is approached from a conceptual angle in *Arcade Operator*. It provides an original playable experiment in non-play, using a low fidelity pixel based arcade brawler mechanic as part a pseudo-simulation where the user performs maintenance and upkeep modes of interaction with arcade machines. *Arcade Operator's* design was informed by both archive and interview based research into the technical and maintenance operations of arcade preservation. As a critical art game it delivers a material deconstruction and reconfiguration of the play level arcade interface, with its development process providing fresh perspectives into the challenge of communicating within constrained interaction parameters.

### 9.1.3 Media Art Contribution

From both practice and theory points of view, this research provides an original first hand insight into contemporary new media art research on retro computing platform aesthetics.

The tacit process of game-based artefact development within legacy technical and aesthetic constraints is articulated in detail, merging game studies, new media art, and game development.

Each artefact defines a new bespoke interactive and conceptual meta experience. This originality has helped each work in terms of accessing publication avenues in both academic and game industry areas. By reaching out to the different areas that inspired this thesis through their unique public platforms it has been possible to facilitate discourse spanning retro arcade game culture, indie game development, and their related academic fields.

#### 9.1.4 *Game Preservation Contribution*

From a software preservation point of view, *VR SuperGun* delivers a tangible, fully functioning prototype capable of addressing issues surrounding archival, preservation, and public interaction with preserved new media artefacts. The artefact points a way for hybridising physical computational hardware and software simulation, by extending legacy videogame platforms into cyberspace. By embodying and reconstituting the physical presence of the arcade machine in digital 3D space *VR SuperGun* removes issues of perishability and impermanence, while opening up paths of discourse into how the authentic can be imbued into a digital reproduction and augmentation of actual reality.

#### 9.1.5 *Technical Contribution*

Aside from its conceptual, experiential, and utilitarian usages, *VR SuperGun*'s features custom developed software and hardware components offering new functionality in interfacing with classic arcade hardware. *VR SuperGun*'s custom javascript code delivers low latency live-streamed video in WebVR. By using the HTML canvas as the target playback environment, the incoming video feed can be mapped to non-standard planes.

The custom Arduino MEGA microcontroller to JAMMA circuit prototype designed for *VR SuperGun* provides an original design for PC based control of legacy arcade systems. In particular *VR SuperGun*'s hardware-to-hardware interface opens up opportunities around the research of tool-assisted speedrun (TAS) and AI-based automated play of unemulated legacy arcade hardware.

#### 9.1.6 *Methodological Contribution*

As a set of original contributions to game studies, game-based art, and their related fields, the thesis spans disciplines not just in terms of practice, but also by linking academic, industry, and art domains.

Peer review has formed an essential and ongoing aspect of this research study. Over 30 research outputs<sup>17</sup> have resulted from this dissertation, published through avenues including conference proceedings, journal articles, invited talks, and exhibitions in new media art and indie game spaces.

Constant engagement with the research community throughout this thesis has positively shaped not only content from each core chapter, but the overall direction of the study.

<sup>17</sup> Please see the [Publications](#) section for further details.

## 9.2 LIMITATIONS

Constraints are a constant and ongoing theme throughout this dissertation, in terms of aesthetics, platforms, materials, and interaction. These limitations serve the creative function of focussing resources and creativity, with the constraint of time playing a constant and significant factor.

While documented here in a linear format, these records are relatively sanitised, relegating many instances where each of the three artefacts hit significant technical barriers to their completion, requiring patience, reiteration, and often lateral thinking in order to realign both material and concept to their intended path.

Indeed, it is difficult to quantify the amount of time spent bug fixing and testing alternate production processes in terms of code, assets, and conceptual approaches, as both the artefacts and supporting text outputs took place in parallel. However once the process was initiated the luxury of building multiple complete prototypes using different authoring packages wasn't an option, only to troubleshoot each obstacle impeding development of the final product in a methodical, systematic manner.

For example, it took over a year of testing different hardware and software combinations to find a setup optimised for *SuperGun VR*'s network live streaming requirements. Eventually the move was made from using a RTC server to streaming direct to the HTML canvas from FFMpeg via Javascript. The sensation of relief felt when this technical implementation succeeded was palpable, having followed several failed implementation attempts.

Also as research focussed on a technical standard originating in Japan, the language barrier has partially impacted on the research findings. However over the course of this thesis, in particular the later half, positive engagement with the Japanese game studies community has greatly assisted in verifying findings on the history of the JAMMA standard, as well as unearthing new first hand historical information.

The interdisciplinary nature of the chosen topic necessitated a broad level of research engagement, presenting the challenge of collating and condensing ongoing developments in related research fields. Time constraints certainly provided a focus but also left open many opportunities for further research. This applies to both the practice and theory aspects of the thesis, and is discussed in the next section.

### 9.3 RESEARCH PRACTICE TANGIBILITY

From this learning journey the insight has become clear that whether the researcher is producing text or producing artefacts, both are forms of reflective practice. At the beginning of this thesis it was important to choose an appropriate term to correctly weight the contribution of written versus the material thesis aspect. Practice *included* rather than practice *led* or practice *based* best conveyed the balanced artistic research direction both intended and followed.

In a 2018 interview, media artist Daniel Rozin commented on the freedom that the public has when they view his artworks since they're free from the baggage of the creator, who is burdened by their knowledge of the many past iterations that proceeded it, and the technical and logistical challenges embodied in it [142]. As such, in addition to the intended messages communicated through the arcade interface meta trilogy, and their function as conceptual provocations to the public who witness and engage with each artefact, from the point of view of the artists they are imbued with an indelible layer of subjective personal memory of the creative journey, and the creative roadblocks that were circumvented along that path.

Additionally ensuring that each artefact was a new contribution to the fields of media art and game-based art meant conducting thorough and ongoing surveys into forms of arcade and videogame-based digital art already in the public domain, and in development. Related to this, the drawn out nature of each (often overlapping) development cycle necessitated the need to publish periodic updates. These updates were carried out both formally through academic and game developer centred venues, and informally through online portfolio updates, video uploads, and social media posts. Each time a piece of the evolving research study was placed in online public view it was automatically timestamped<sup>18</sup>. By engaging with the research and developer communities on an ongoing basis throughout the thesis journey essential peer review and user feedback was gathered on a consistent basis, critically shaping and improving the overall research direction and quality.

<sup>18</sup> Please refer to [Appendix A](#) for a selection of online media links.

### 9.4 FUTURE TRAJECTORIES

There are numerous ways in which the findings of this thesis can be developed further. As mentioned in the previous section there is much scope for a continuation of the game history aspects of this thesis, by further uncovering the technical, aesthetic, and production processes of JAMMA era developers of both the Japanese arcade in-

dustry and the international home conversion markets. The artisan work of modern indie arcade developers worldwide who continue the spirit of 1980s and 1990s arcade gaming also warrants academic engagement as a craft level take on an originally industrially driven process.

Engagement with the retro community outside of the academy has played an essential part in this research journey. The scale of work carried out in archiving and cataloguing classic arcade games by the collector communities, alongside the restoration and maintenance of classic arcade games by the deceptively named hobbyist community play a critical role in preserving the past of arcade gaming. The preservation practices of the current generation of arcade collectors certainly deserves reflective scholarly treatment from a game studies angle.

Media art's symbiosis with videogame aesthetics in the form of game art, art games, and other forms of expression spawning from videogame culture, in particular arcade culture, provide multiple additional routes for future research. Whether or not 'peak retro' is yet achieved, the current prominence of arcade nostalgia is the latest in a series of recurrent crossover waves of arcade culture into modern pop culture that originate at the beginnings of Atari mania and *Pac-Man* fever. The semiotics of arcade culture and their enduring presence present further game studies related angles of enquiry.

On the artefact side of this study, *VR SuperGun* is the most recent of the three media art works and also the artefact that has the most potential to grow and develop further. In its present desktop prototype form, *VR SuperGun* delivers playable streaming over remote network connections, through a low polygon aesthetic befitting of the era that inspired it. The codebase, hardware, and concept offer multiple development opportunities. These include installation in art gallery and museum environments, taking a cue from *Control*'s public incarnations by presenting the artefact experience through multiple installation modes.

## 9.5 JAMMA ERA ARCADE LEGACY

This research journey has been a full immersion into the material of JAMMA era arcade games as creative and aesthetic digital platforms. The practice-included platform studies influenced methodology devised for this dissertation has opened the black box of JAMMA era arcade platforms through multiple complimentary levels of research practice, bridging historic, technical, and artistic enquiry.



Although existing in separate strands of arcade culture, and motivated by different factors, the three parallels of piracy, preservation, and artistic experimentation have served as necessary claims of agency over the commercially sealed, consumer level interface of the arcade platform, contributing to the continued archival, active play, and cultural exposure of retro arcade games, platforms, and aesthetics. As evidenced from early days of arcade development, even the industry have reconfigured their play only technologies into digital artistic toolsets to drive innovation, setting an early precedent for the creative reappropriation of videogame platforms for artistic means.

The JAMMA arcade standard was introduced by the Japanese arcade industry as a pragmatic move to ensure the survival and continued growth of the arcade industry. This adaptability is imbued into arcade games, the arcade genre reaching beyond coin-ops and game arcades across platforms. Clearly the term arcade applies not just as a platform and genre, but also as a born digital aesthetic.

Simultaneously shaped by and defying material boundaries, the signature style of JAMMA era arcade constraints remain pervasive not just in videogame culture, but outside the digital domain in the form of game art, contributing to the visual language of pop culture at large. Certainly the playful aesthetic experiences produced by classic arcade development teams are part of the lineage of digital art, the arcades their exhibition spaces, and each credit token a bargain admission fee.

Part V

APPENDIX





## ARTEFACT WEBLINKS AND DOWNLOADS

---

### A.1 ARTEFACT A: CONTROL

*Control* project page

<http://kierannolan.com/control>

*Control* download at Itch.io

<https://kierannolan.itch.io/control>

*Control* in play at Materiality, Galway

<https://vimeo.com/128570538>

*Control*, Materiality exhibition space, Galway

<https://vimeo.com/128570417>

*Control* YouTube playthrough compilation

<https://tinyurl.com/controlyoutube>

*Control* interview with Built To Play

<http://builttoplay.ca/podcast/2015/3/3/built-to-play-55-interface-the-machine>

### A.2 ARTEFACT B: ARCADE OPERATOR

*Arcade Operator* project page

<http://kierannolan.com/arcadeoperator>

*Arcade Operator* game download at Itch.io

<https://kierannolan.itch.io/arcade-operator>

*Arcade Operator* trailer

<https://vimeo.com/217395627>

*Arcade Operator* soundtrack

<https://soundcloud.com/kierannolan/sets/arcade-operator-ost>

### A.3 ARTEFACT C: VR SUPERGUN

VR *Supergun* project page

<http://kierannolan.com/vrsupergun>

VR *SuperGun* trailer video

<https://vimeo.com/360043737>

VR *SuperGun* prototype streaming test to VR CRT monitor

<https://vimeo.com/285740567>

VR *SuperGun* A-Frame canvas stream to curved display test

<https://vimeo.com/279057169>

VR *SuperGun* arcade PCB to A-Frame WebVR streaming prototype

<https://vimeo.com/266019568>

VR *SuperGun* latency test A

<https://vimeo.com/268202711>

VR *SuperGun* FFMpeg desktop capture to A-Frame WebVR via JS

<https://vimeo.com/250266407>

## INTERVIEW

---

 INTERVIEW WITH PAT BROSANAN, 29TH JULY 2016

This interview provides a view of 1980 and 1990s arcade history from the vantage point of manufacturing, sales, and repair of arcade videogames from a first hand industry perspective. While informing the thesis in its totality, it has particularly influenced the research and development of the *Arcade Operator* and *VR SuperGun* artefacts, both of which are linked thematically to the material exterior form and inner electronic and mechanical assemblages of arcade coin-op platforms.

While the arcade game software is contained sealed in the game board, its end user experience is inexorably further shaped by the design and implementation of the arcade cabinet. In addition to detailing the arcade assembly line process, the challenges of maintaining 1980s and 1990s arcade hardware amidst the ongoing evolution of platform technologies are also discussed.

Pat Brosnan:

About 94, 95 Time Warner had owned us about that time and they wanted to sell, so they sold more or less all of Atari to another company, (that did *Space Invaders*), Bally Midway. But they didn't sell off the Irish entity, so Namco UK bought us and part of the arrangement was that we would continue to have the licensing the build the Atari games for a period of two to three years. So then after that wound up, the three years, and Atari didn't review that agreement, the factory in Tipperary closed down.

We changed the name to Atari Games, originally it was Atari, because it was started by Nolan Bushnell and Atari came from the Japanese board game called *Go*, and we had various owners, we had Warner Bros, and then we had Time Warner and other people, between they sold the consumer division was the Atari 2600 and the Atari 100 / 800 business it went to Jack Trammell who was the president then of Commodore, and he wanted the brand Atari so then we had to change to Atari Games which was the coin-op division.

Kieran Nolan:

What did the job of Technical Manager entail?

PB:

I started off first as the field service engineer, and effectively what that meant is all the games that Atari were selling, we would sell to distributors in various countries and if they in turn were sold to the various arcades or wherever a video game was going. So they would also have repair technicians, so if they couldn't repair the machines so they would come back to us in Tipperary to be repaired. Also I was involved in the various trade shows that we would have a coin-operated division perspective or be able to give people training sessions on things as well. I then went and took over, my manager had left, and he had both field service and responsibility for manufacturing from the electronics, technical IT perspectives, but I only had the European field service team, so I became the manager of that, and two years after that I took over the whole thing, I became the Technical manager.

So not alone was I responsible for the field service area, I was also responsible for getting the games shipped out. So the States would build and design the systems, but we had to change the specs obviously from a European perspective, so we had to source the correct power supplies, check that out, source the various monitors, make sure that it was capable of the right monitors. Most of the monitors at that time would have just been RGB but when we went to laser video we had to make sure that it would work for PAL rather than NTSC and then finally we were responsible for putting the CE mark on it so that it would pass the European certifications.

KN:

You're credited on Mobygames.com in the development of *Hard Drivin'*, what was it like been involved with that project?

PB:

I wasn't involved in the development of the game but they used me as a sort of contributor as such, you know, things that would work for Europe or other bits and pieces, and that was the first 3D game that they developed. The big sit in one had three monitors at the same time. At that time, back in 1985 some of the driving schools, especially in the States, were using them for their (original) theory tests and stuff like that.

KN:

So it was marketed as a simulator as well as a game?

PB:

Correct. So yeah I was listed on the thing. Now I've always been involved in assisting development but I think that one is where my



name finally came up in lights on one of the game developments anyway.

KN:

Did you use the 56 pin JAMMA standard in the cabinets built there?

PB:

That standard doesn't ring any bells but the thing is that we were always using either the AMP or Molex connectors for the majority of the things, and there was certain regulations that we had to follow, certain type of pin types on your connector for power, certain pin types for video and then the ferrite beads to make sure there was no interference, and things like that. I know in the early 90s that they did start building modular cabinets so they could put in multiple different types of gaming boards. Or else what they did do is they had designed more or less the first of its species, the big motherboard and then all the gaming software was built into what was called a cartridge. Now it wasn't a cartridge in the home sense but the cartridge was another PCB that would just connect up into the motherboard and that's where all the memory for the software for the game was installed for.

KN:

Were you ever called to repair a game that was a copy?

PB:

Oh you'd definitely know if they were a copy of not anyway, most of that sort of piracy thing was taken care of by the States. If we saw them we did take a number of pictures. Now obviously from a cabinet perspective we'd see a number of different clones, from a technical perspective you would try to see it but it was always done on a different level, and you could always detect the fake.

KN:

It seems that bootleg arcade games were widespread in the 1980s and 1990s, apparently *Street Fighter II* was the biggest selling arcade game in Mexico when it was originally released, yet Capcom had no distributor there.

PB:

I think it was as big as that, they (the competitors / pirates) did reverse engineering, a lot of it. The thing was there were three patents we had at one stage for our graphics and stuff like that. The original one was the vector graphics, *Tempest* and those sort of games, *Asteroids* even. There was the one that was used for the *Gauntlet* game, and I can't remember that particular design, and then *Hard Drivin'*

was patented as well.

KN:

The Atari legal team must have been kept busy?

PB:

Yeah, the year that it happened there was a lot of reverse engineering going on with the arcade games, there was a lot of reverse engineering going on with Nintendo games as well, the home games. So it seemed to have been the year of doing that (in around 1995). So the Nintendo console for home was quite the big one, from that perspective Nintendo were trying to keep a stranglehold on the business because the likes of Atari and Namco and Sega, Nintendo would say "right, you're only going to build three games for us this year, and we build and you're only getting revenue for X thousand or X millions cartridges". So there were those type of things at the time. We had built two different kinds of cabinet, one with a high resolution monitor and one with a standard resolution monitor and like I said they built these motherboards so that they would stick these cartridge PCBs into them. So the cabinet would stay the same because the cabinet would last a lot longer but all people would have to do was buy the cartridge board and maybe one or two different kinds of cables to change it to the control panel and make it as generic as possible.

KN:

Was that a way of trying to keeping costs down, for the manufacturers, the people running the arcades, or a bit of both?

PB:

I think it was a bit of both, what they decided to do was have a constant revenue stream coming in. So they had already bought the actual cabinet, they had already bought all this, and then all they had to do was buy the cartridges so they were always constantly getting games out quickly because they didn't have to redesign the graphics and all the rest of it. I mean, two games, *Playboy* was the original cabinet used for the high resolution games, and *Marble Madness* was the other one with standard resolution.

KN:

Were there ever any changes to the game code or content that had to be made for export markets? Did you ever encounter that?

PB:

No, the thing is that they always kept the games rather generic, so they didn't have any problems with that. The main thing was that they had to change for the different languages. The ROMs they had

to change were for to the different languages. I remember with the *Hard Drivin'* one if you saw the sit down version which had the three monitors, the seat would push back and rotate about 90 degrees so you could get into it. And so when you sat back in front of the three monitors and the game started there was a magnet under the seat that was locking it into position, and there was a pushbutton there so if anyone was physically sick or needed to get out of the seat before the game ended. I always remember this one, they translated the button which was 'eject' in German, but they didn't translate it properly, because it meant an inappropriate term. So we did have a couple of those kind of problems going on from time to time, but that was primarily the things we had, that somehow the translation was screwy, other than that there was very little change. The hardest one that we had to do, was that when we went to laser video, you did have the Philips Laser Vision, what would now be called a CD player / DVD player, a commercial model, and you had to get the discs for them that were LP sized, so they had to be translated.

*Mad Dog McCree* was a licensed game that Atari took over. So there was a company in Los Angeles that had the idea and then we took it over and we sold it across the world. We used a big 45" projector, it was back display projector that was used. That was heavy. Then we had the Philips Laser Vision was doing that, and unfortunately one the problems that we had with that was that it was still relatively new. The Laser Videos were still using the laser helium tube rather than the ICs of the time, and they weren't geared for industrial use so a lot of the problem that we had was you try to fans cool but also avoid dust getting into them, so unfortunately dust got onto the mirror of the laser and unfortunately as well Philips were still using all the old technology, so they were still using transistors instead of ICs, the laser helium tube rather than the IC laser that we now use today, and it was good, and one of the things we had to do with that was he had to be trained with Philips in Eindhoven and then I had to train all of the distributor's technicians on how to repair those laser videos.

KN:

I have great memories of playing *Mad Dog McCree*, it was an interactive cinema experience way ahead of what home computers could do at the time.

PB:

Exactly, and the way it had the gun, you know, where to point and all that. But you know the first of the species of laser video was *Dragons Lair*, from Cinematronics. Again we licensed that from Cinematronics. It was Sullivan Bluth, but Cinematronics had the licence at the time.

KN:

Were you involved with licensing of Atari games for home computers?

PB:

No, that was all done in the States. I don't know if you know this or not, but the Dell building in Limerick was the original Atari consumer building in Ireland.

KN:

No I didn't know that, so that's where the consoles and computers were dealt with?

PB:

Correct, so the thing is Atari started originally in Tipperary and then they looked at the consumer division, and they started in the Ballysimon road, and then they moved out somewhere into the Ennis road, I can't remember where, and they had the building here. They built it, and when Dell moved into they built another half to it. The sign for Atari is still on the campus but it's just knocked over.

KN:

While you were working at Atari did see the systems used to develop the games?

PB:

Not really, I did get trained up on a number of them, the best one I got trained up on was *Gauntlet*. I know when I started out back in '83 *Star Wars* was the big thing at the time, so they did the trilogy, *The Empire Strikes Back*, that was in a stand up cabinet. The designs they did stop animation, the one with the T-Rex, the dinosaurs, the fighting game, *Primal Rage*, so I saw a lot of the guys doing the stop-start animation, I was there when they were doing that, I did see some of the older machines, when they doing *Tempest* and *Asteroids*, they weren't developing any more 3D vector games at the time but I seen the whole thing. One of the guys who was Irish but that had moved over to the States had developed something called the P.A.T. (Programmable Atari Testbed) which was the programmable Atari tester, so it was a black machine that you could hook up any connectors to, and it had two monitors, you could simulate the arcade cabinet. Then they had some other machine they used to test how a monitor would see if the graphics were suitable for that monitor.

There was another thing I saw at the time, it was a two monitor game that played Cyber American football<sup>19</sup>, so you could have up to four players, playing offence and defence. Both monitors were at 45

<sup>19</sup> *Cyberball*, 1998.

degree angles, so you couldn't see what your competitor was doing.

KN:

What was the work environment like at Atari Ireland when you worked there?

PB:

Well you had a manufacturing line, and then you had a section for everyone to make what we called the harnesses, which was the cabling. Then you had the offices where you would have the production manager, the harness manager, the warehouse manager, the shipping manager, customer service manager, field service and technical manager - which was me. You had the purchasing manager, you had the MD, and then you had the finance people as well. And we used a lot of the local manufacturing. One of the things I was proud of, when I was going to University of Limerick, my first was doing mechanical engineering along with the electronic engineering I was studying, and it was only when I started with Atari, and probably 3 years after I started that even I designed some of the control panels and even I designed some of the metalwork that I thought I would never do as an electronics engineer. So doing the cab and all the rest of it was fantastic.

KN:

So you were actually designing the control panel and the cabinet itself?

PB:

Yeah, and in fact we had a manager also that did all the woodwork for the cabinets as well. Originally they were outside Clonmel, but then we brought them into the site in Tipperary as well, and that's where all the cabinets were made. So most of the cabinets were made with MDF, or chipboard, and then we would all have to discuss what we had to change, the width of material or whatever, or whatever we thought would be stronger for the European market. So basically we got a whole bill of materials and all the drawings, then we had to adapt them for European standards and specs.

KN:

The artwork that went on the side of the cabinets, did you guys design that or modify it in any ways?

PB:

The generic ones, no, but sometimes we did have to redo it. One of the things we did in Tipperary, was you could never always guarantee you'd always have a game a month to manufacture. So what we had

to do was make sure we were busy so we also contracted ourselves out to the likes of Sega and Namco, before we became Namco, to build some of theirs. And that's where we would have changed some of their graphics because you know they would have the graphics for the Japanese market, but our cabinets would be different, they might be slightly wider, or we'd even have to build the cabinet for them, so that's where we would have had to adjust their graphics.

KN:

Were you contracted to Atari, or was it Atari taking on Sega work?

PB:

It was Atari taking on Sega work.

KN:

What was the process of building arcade cabinets like? Did each build take long?

PB: What the guys would do in the wood area was cut out all the pieces and stack them all up like IKEA put it together. They would probably get 20 or 30 of the cabinets made up a day, at least, and then it would be pushed over to the main manufacturing area, we had various sections on the manufacturing floor. First station would be where we would put in the cabling / harnessing. Second station would be putting in the monitors and maybe the utility panel in there, and then putting on the bezels, glass, control panel. And then sub-stations to make the harnesses, make the control panels with joysticks, driving steering wheel, buttons or whatever, and then it would go through our quality control. Now I would say that you had two different versions of your cabinets. A, you could have actually had the stick on artwork with adhesive that you would put on, or else sometimes you would have the silkscreen process been put on the actual gable ends of the cabinets before they're assembled.

With the cabinets we had two processes, one could be a decal, which would be adhesive artwork. The other one would be screen printing. So you had the various layers of screening, depending on the colours you are using and then he would just screen on the artwork that way.

KN:

Did the computer and console ends of Atari communicate with the arcade end, or were they separate entities?

PB:

They were more or less separate entities, and remember that around

1999, earlier than that, 1990, somewhere around that time that we had sold the consumer edition, which was the Atari 400 and the 800 and the VC 2600. We had sold that off so it became a separate entity. Now, going back to the owners, originally it was Nolan Bushnell, he was the founder of it, then he sold it to Warner Brothers, and Nolan was told that he had to stay out of the industry for seven years which was part of the deal. He then came in and tried to do something else back in the mid-90s, 95 or that, he started attending some of the trade shows again and he was coming up with a company of his own again, and around that time too Microsoft were talking about what is today the Xbox but they were looking at an arcade type machine as well.

But going back to the owners and the likes of Warner Brothers, then we were sold, and then we were bought by Time Warner. Every time that Warner Brothers and Time Warner bought us they always thought there was going to be some advantage for them, that they could, have a hit movie and they could make it an arcade game, and stuff like that. And other bits and pieces that never transpired, but that was their ambition anyways. Eventually, Time Warner was getting into other acquisitions, they bought some TV stations at the time, so they needed to get capital for that, so that's why they sold us to Bally Midway. That was in Chicago, and then sold the Irish division off to Namco.

KN:

It's interesting to see how different licences and IPs were transferred between companies.

PB:

Yeah, I should have said before we were sold to Bally Midway, Namco did own us. Because our president of Atari was a Japanese person who reported to the Namco president. In the Hideuke Nakajima was our president, Nakamura was the president of Namco at the time.

KN:

Did you ever go to Japan?

PB:

I had wished, but I never got the opportunity.

KN:

Did the Japanese Atari / Namco managers ever travel over to Ireland?

PB:

Oh yeah they did, quite a bit. Nakajima would have been quite a bit, and we would have talked to him. He was an interesting guy. and



Nakamura we didn't see too much off, and he didn't have a lot of English anyway. So we would have seen him at the trade shows when they were in the Olympia Stadium and then Earl's Court.

KN:

Did they ask you to change any designs, or how the games worked, or were they just checking in?

PB:

It was primarily checking in. Nakajima was a good guy, his English was impeccable, he was a smart man, and things didn't change too much when he took over, it changed probably more in the States. Obviously been more shrewd, and the same with us, been shrewd, but most of the stuff didn't change for us anyway.

KN:

When you were working for Atari technical support, were there any issues that arose more than others?

PB:

It was towards when I was leaving Atari around 97, the worst thing that ever started happening was we started going towards surface mounted chips. Trying to troubleshoot them by lifting the leg without moving the pad on the circuit board, and then trying to relay them was a nightmare. You know we probably destroyed a number of boards. We were trained on the right equipment, and all the rest of it, but it was a nightmare. I think sometimes the distributors were lazy, they didn't allow their techs to fix a lot of problems. Some of them would have been due to just not knowing how the video generation was happening.

What I mean by that was the interlaced video, one section of it was creating the character, and the other section of it was creating the background, and if you didn't know that well enough then some of your troubleshooting would be forever. The vector generator boards with Tempest and Asteroids, it was always one particular area that failed and seemed to be the generator for the XY vector graphics was always a thing that failed. Obviously Laser Video was a pain in the backside because you had these big bulky things coming back at you. To be quite honest, because they were using the helium neon tube, it had huge mirrors, so you could have adjusted it quite easily, but by the time you had shipped it back to the distributor it could have been out of whack again because the mirrors were quite sensitive as well.

Most of the games that were developed were developed by the guys in California. At the time it was a laid back California time, even the

atmosphere was going back to the 70s, because you'd see these guys with long hair and walking bare foot, and it was just making sure that the creative juices kept coming with ideas and stuff like that. Even sometimes the sounds and music that they made were similar to the equipment that you'd have in filmmaking, the big desks you could get your bings and bongs and that easy. Actually they developed a chip to make the music called the Pokey, and then they made a four channel one called the quad Pokey.

KN:

Their creativity has had such a lasting influence, in music, games, and popular culture in general.

PB:

Yeah, that's where going back to the likes of Nakajima, we had all the Atari games developed for Nintendo. There was a bit of reverse engineering going on and there was a lawsuit going on at one stage between Atari and Nintendo but I don't think it ever came to anything anyways, because I think both parties won right?

KN:

Was that Pong?

PB:

No, the thing was that when they had a Nintendo game, Nintendo had a stranglehold, so they would only allow 3 Atari titles, allow them to produce X amount of volume on those three titles. There was a bit of reverse engineering, I don't know by whom, but then Atari started doing more than just three titles. Nintendo sued them and then Atari counter-sued them. So Nintendo sued them for the reverse-engineering perspective for doing more titles than they were contractually obliged to, and then Atari counter sued because they were placing a stranglehold, they were trying to hold the competition, so there was a lot of that going on as well.

PB:

You do know that Steve Jobs worked at Atari? Woz worked for them as well.

KN:

Do you think he would have picked up a lot while he was there?

PB:

More than likely.

KN:

I read a story about the young Steve Jobs been sent to Germany for Atari, he put his bare feet on the meeting table, and sat there staring down a board of directors.

PB:

That was Atari true and true. Fine, I came in after the real boom of the video and arcade games about 83, I was just kind of towards the tail end, but you know, Nolan always had a loose vibe. It was never created like a business. There was never once you saw anyone wearing tie. I remember one of the engineering VPs had a tie once, but that was because he was meeting some president at the time, but other than that, especially in California, they were definitely in jeans. You'd see them in jeans, you'd see them in open toed sandals, long hair, open neck shirts and all the rest of it, even t-shirts. But if you think of it, that was California in the whole genre at the time.

KN:

Was Ireland much similar culturally?

PB:

It was very relaxed. Again, probably the only person you would have seen with a tie on was the managing director at the time. But I'll tell you one of these things, is when I started, Kevin Hayes, was the managing director at the time, and to me, when I met Kevin when I started on my first day, he reminded me more of a college grad because he had one of these big wooly Aran type brown jumpers, he had a big thick beard, and the hair wasn't long but it was longish, and I said "this guy is running the company?". Kevin's a great guy, and Kevin went on to do bigger and better things, he went on to run Namco for ages anyways. But anyways sales directors and sales VP I dealt with, they were great guys, they opened my eyes to a lot of things, I have a lot to thank them for. I mean, I was only just saying that recently, some of them died, one of them was Shane Greggs, the other guy was David Smith. They introduced me to a lot of different food anyways, such was all the travelling. They introduced me to the likes of Japanese, which now wouldn't be such a big deal, but in the mid to late 80s Chinese, Japanese and the rest of that kind of food wasn't really the norm, and a lot of cultural things and the rest, I have a lot to thank for to Atari for opening my eyes to.

## BIBLIOGRAPHY

---

- [1] Julian. *SEGA 3D Classics – 3D Thunder Blade – Part 2*. May 2015. URL: <https://web.archive.org/web/20170720084402/http://blogs.sega.com:80/2015/05/13/sega-3d-classics-3d-thunder-blade-part-2/> (visited on 12/07/2018).
- [2] Mike. *JAMMA Standard Pinout Class*. 2017. URL: <http://www.mikesarcade.com/cgi-bin/spies.cgi?action=url&page=Jamma.html&type=pinout> (visited on 11/18/2018).
- [3] A-Frame. *A-Frame – Make WebVR*. 2018. URL: <https://aframe.io/> (visited on 11/26/2018).
- [4] Espen Aarseth. “Computer Game Studies, Year One.” In: *Game Studies* 1.1 (July 2001). URL: <http://gamestudies.org/0101/editorial.html>.
- [5] Afilamazas. *CONTROL*. Nov. 2013. URL: [https://web.archive.org/web/20131211002144if\\_/http%3A%2F%2Fwww.elpixelilustre.com%2F2013%2F11%2Fcontrol.html](https://web.archive.org/web/20131211002144if_/http%3A%2F%2Fwww.elpixelilustre.com%2F2013%2F11%2Fcontrol.html) (visited on 11/10/2018).
- [6] Nathan Altice. *Emulate the Emulators*. Mar. 2012. URL: <http://metopal.com/2012/03/15/emulate-the-emulators/> (visited on 01/23/2013).
- [7] Nathan Altice. *I am Error: The Nintendo Family Computer / Entertainment System Platform*. English. Cambridge, Massachusetts: MIT Press, June 2015. ISBN: 978-0-262-02877-6.
- [8] Amigos Retro Gaming. *I answer the question, what happened to the Zool arcade coin-op game?...*  Jan. 2019. URL: <https://youtu.be/Y-qSeHCNtEU> (visited on 01/30/2019).
- [9] *An interview with Marc Djan*. 2012. URL: <http://codetapper.com/amiga/interviews/marc-djan/> (visited on 02/10/2018).
- [10] Christian Ulrik Andersen and Soren Bro Pold. *Interface Criticism: Aesthetics Beyond Buttons*. Aarhus University Press, Mar. 2011. ISBN: 87-7934-504-2.
- [11] Thomas H. Apperley. “Genre and game studies: Toward a critical approach to video game genres.” en. In: *Simulation & Gaming* 37.1 (Mar. 2006), pp. 6–23. ISSN: 1046-8781. DOI: [10.1177/1046878105282278](https://doi.org/10.1177/1046878105282278). URL: <https://doi.org/10.1177/1046878105282278> (visited on 06/07/2015).
- [12] Thomas Apperley and Jussi Parikka. “Platform Studies’ Epistemic Threshold.” In: *Games and Culture* 0.0 (2015), p. 1555412015616509. DOI: [10.1177/1555412015616509](https://doi.org/10.1177/1555412015616509). URL: <http://dx.doi.org/10.1177/1555412015616509>.

- [13] Cory Arcangel. *Super Mario Clouds Cory Arcangel's Official Portfolio Website and Portal*. 2002. URL: <http://coryarcangel.com/things-i-made/supermarioclouds/> (visited on 01/23/2013).
- [14] Brian Ashcraft. *Arcade Mania: The Turbo-Charged World of Japan's Game Centers: The Turbo-charged World of Japan's Game Centers*. English. Tokyo ; New York: Kodansha International, Nov. 2008. ISBN: 978-4-7700-3078-8.
- [15] Brookhaven Science Associates. *BNL | History: The First Video Game?* 2019. URL: <https://www.bnl.gov/about/history/firstvideo.php> (visited on 08/03/2019).
- [16] Atari. *Atari - The BOOK - Guide to Electronic Game Operation & Servicing*. English. 1980. URL: [http://archive.org/details/atari\\_thebook](http://archive.org/details/atari_thebook) (visited on 06/17/2016).
- [17] BEEP! Game Center. *CONTROL BOX: los SUPERGUN japoneses (I)*. es-ES. June 2016. URL: <https://beepgamecenter.com/2016/06/13/control-box-los-supergun-japoneses-i/> (visited on 07/10/2017).
- [18] BYOAC Wiki. Wiki. July 2010. URL: <http://wiki.arcadecontrols.com/wiki/JAMMA> (visited on 03/17/2015).
- [19] Ralph H. Baer. *Pong-Story : Who did it first ?* URL: <http://www.pong-story.com/inventor.htm> (visited on 10/13/2018).
- [20] Walter Benjamin. *The Work of Art in the Age of Mechanical Reproduction*. English. Trans. by J. A. Underwood. London: Penguin, Aug. 2008. ISBN: 978-0-14-103619-9.
- [21] Matteo Bittanti. *Gamescenes: Art in the Age of Videogames*. Johan & Levi Editore, 2009. ISBN: 88-6010-010-0. URL: <http://www.librarything.com/work/5568876/book/64074383>.
- [22] Ian Bogost. *How to Do Things with Videogames*. English. Minneapolis: University of Minnesota Press, Aug. 2011. ISBN: 978-0-8166-7647-7.
- [23] Stephanie Boluk and Patrick LeMieux. *Metagaming*. English. Minneapolis: University Of Minnesota Press, Mar. 2017. ISBN: 978-0-8166-8716-9.
- [24] Adam Bousley. *DICE*. Nov. 2016. URL: <https://sourceforge.net/projects/dice/> (visited on 10/28/2017).
- [25] Paolo Branca. *Protopixel HARDcade: Interactive 8bit installation by VjVISUALLOOP*. 2006. URL: <http://www.vjvisualloop.tv/protopixel.html> (visited on 11/16/2012).
- [26] Toby Broyad. *Atari System 2 Hardware (Atari)*. 1999. URL: <http://www.system16.com/hardware.php?id=769> (visited on 12/25/2014).
- [27] Toby Broyad. *CPS Hardware (Capcom)*. 2014. URL: <http://system16.com/hardware.php?id=793> (visited on 12/25/2014).

- [28] Toby Broyad. *System 16 - Irem M62 Hardware (Irem)*. 2014. URL: <http://www.system16.com/hardware.php?id=737> (visited on 12/02/2016).
- [29] Toby Broyad. *System 16 - Taito Wolf System Hardware (Taito)*. 2014. URL: <https://www.system16.com/hardware.php?id=671#3394> (visited on 09/15/2018).
- [30] Van Burnham. *Supercade: A Visual History of the Videogame Age 1971-1984*. New Ed. MIT Press, Nov. 2003. ISBN: 0-262-52420-1.
- [31] Preston Burt. *The Virtual Reality Game Room of Your Dreams*. Mar. 2015. URL: <https://geekdad.com/2015/03/virtual-reality-game-room/> (visited on 03/17/2015).
- [32] CAPSoff. *CAPSoff*. URL: <http://caps0ff.blogspot.com/> (visited on 11/10/2018).
- [33] Damon Caskey. *Chrono Crash*. 2012. URL: <http://www.chronocrash.com/forum/> (visited on 11/17/2018).
- [34] Mark Caswell and Nick Roberts. "Review: Midnight Resistance." In: *Crash* 78 (July 1990), p. 40. URL: [https://archive.org/details/Crash\\_No.\\_78\\_1990-07-Newsfield\\_GB](https://archive.org/details/Crash_No._78_1990-07-Newsfield_GB).
- [35] Ruth Catlow. *Artists Re: Thinking Games (Liverpool University Press - Foundation for Art Creative Technology)*. 2010. ISBN: 1-84631-247-7. URL: <http://www.librarything.com/work/10246589/book/63007536>.
- [36] Daniel Cermak-Sassenrath. *Playful Disruption of Digital Media*. New York, NY: Springer Berlin Heidelberg, 2017. ISBN: 978-981-10-1889-3.
- [37] John St Clair. *Project Arcade: Build Your Own Arcade Machine*. en. John Wiley and Sons, Jan. 2011. ISBN: 978-1-118-03883-3.
- [38] *Classic Arcade Cabinets: Street Fighter II*. en. 2016. URL: <http://www.classicarcadecabinets.com/street-fighter-ii.html> (visited on 07/16/2018).
- [39] Karen Collins. *Game Sound: An Introduction to the History, Theory, and Practice of Video Game Music and Sound Design*. English. Cambridge, Mass: MIT Press, Sept. 2008. ISBN: 978-0-262-03378-7.
- [40] JAMMA Technical Committee. *JAMMA Video Q&A*. 2000. URL: [https://web.archive.org/web/20040227125402fw\\_/http://www.jamma.or.jp/siryou/siryou02/JV\\_QA3R.pdf](https://web.archive.org/web/20040227125402fw_/http://www.jamma.or.jp/siryou/siryou02/JV_QA3R.pdf).
- [41] Mia Consalvo. *Cheating: gaining advantage in videogames*. eng. First MIT Press paperback edition. Cambridge, Mass.: Massachusetts Institute of Technology, 2009. ISBN: 978-0-262-51328-9 978-0-262-03365-7.

- [42] Peter Culshaw. 'So I pitched my Oscar Wilde film to Spielberg'. Apr. 2004. URL: <http://www.guardian.co.uk/music/2004/mar/21/popandrock.shopping> (visited on 01/24/2013).
- [43] Cybearg. *New 2600 Homebrews - Heartbreak | Fix-It Felix Sr. | Joy Ride - Homebrew Discussion - AtariAge Forums*. Mar. 2013. URL: <https://atariage.com/forums/topic/210515-new-2600-homebrews-heartbreak-fix-it-felix-sr-joy-ride/> (visited on 10/29/2019).
- [44] Richard Davey. *Arcade Font Writer*. 2014. URL: <http://arcade.photonstorm.com/> (visited on 11/16/2018).
- [45] Joseph DeLappe. *MGandhi's March in Second Life : Joseph DeLappe*. URL: <http://www.delappe.net/game-art/mgandhis-march-to-dandi-in-second-life/> (visited on 08/08/2018).
- [46] Arsenault Dominic and Larochelle Audrey. "From Euclidean Space to Albertian Gaze : Traditions of Visual Representation in Games Beyond the Surface." In: *DiGRA &#3913 - Proceedings of the 2013 DiGRA International Conference: DeFragging Game Studies*. Aug. 2014. ISBN: ISSN 2342-9666. URL: [http://www.digra.org/wp-content/uploads/digital-library/paper\\_242.pdf](http://www.digra.org/wp-content/uploads/digital-library/paper_242.pdf).
- [47] Future Driver. *Fix It Felix Jr. MD*. Mar. 2013. URL: <http://68000.web.fc2.com/felix/index.html> (visited on 10/29/2019).
- [48] Nick Dwyer and Tu Neill. *Diggin' in the Carts - The Rise of VGM- Ep 1 - Red Bull Music Academy Presents*. Sept. 2014. URL: <https://www.youtube.com/watch?v=m8z8-SKg3WU> (visited on 11/30/2018).
- [49] Edge. "Firing the Supergun." In: *Edge 3* (Dec. 1993), p. 74.
- [50] Edge. "Zool: First PC game to hit arcades." In: *Edge 6* (Mar. 1994).
- [51] *Elf/Pandora's Box/Chamma to JAMMA adapter*. 2019. URL: <https://www.mikesarcade.com/cgi-bin/store.pl?sku=JA-CHAMMA> (visited on 06/11/2019).
- [52] Elite. "Ghosts 'N Goblins." In: *The One 19* (Apr. 1990), p. 51.
- [53] Barrie Ellis. *Switch Gaming - Accessible video games*. 2013. URL: <http://oneswitch.org.uk/4/games/0index.htm> (visited on 05/03/2013).
- [54] *EmuVR*. en-US. URL: <http://www.emuvr.net> (visited on 07/26/2018).
- [55] Entter. *Entter's Pixelart Exhibition at Fousion Gallery*. en. Apr. 2014. URL: <https://vimeo.com/91708492> (visited on 12/08/2018).
- [56] John M. Evans et al. *Standards for computer aided manufacturing*. eng. National Bureau of Standards. URL: [http://archive.org/details/standardsforcom7610evan\\_0](http://archive.org/details/standardsforcom7610evan_0) (visited on 11/26/2018).

- [57] Famicom Fan. *SUPER GUN - vocus*. en. Nov. 2017. URL: <https://vocus.cc/hindsight-bias/5a120c85ecea97b4023b33> (visited on 03/07/2018).
- [58] Debora Ferrari and Luca Traini. *Neoludica: Art and Videogames: 2011 - 1966*. English. 1st Edition edition. Milano: Skira Editore, June 2012. ISBN: 978-88-572-1164-0.
- [59] Mary Flanagan. *Critical Play: Radical Game Design*. English. Cambridge, Mass.: MIT Press, Mar. 2013. ISBN: 978-0-262-51865-9.
- [60] Flinnster. *Wonderboy (SEGA) MAME Cabinet*. July 2016. URL: <https://mameart.wordpress.com/2016/07/20/wonderboy-sega-1986/> (visited on 07/17/2018).
- [61] Antonin Fourneau. *Arcade Concrete*. fr-FR. 2013. URL: <http://www.antoninfourneau.com/portfolio/arcade-concrete/> (visited on 11/05/2018).
- [62] Megatron's Fury. *Jim Bagley Interview*. en. 2014. URL: <https://www.retrogamegeeks.co.uk/jim-bagley> (visited on 11/05/2018).
- [63] Alexander R Galloway. *Gaming: essays on algorithmic culture*. English. Minneapolis [u.a.: University of Minnesota Press, 2007. ISBN: 0-8166-4850-6 0-8166-4851-4 978-0-8166-4850-4 978-0-8166-4851-1.
- [64] Alexander R. Galloway. *The Interface Effect*. Polity Press, Sept. 2012. ISBN: 0-7456-6253-6.
- [65] Alison Gazzard. "The Intertextual Arcade: Tracing Histories of Arcade Clones in 1980s Britain." In: *Reconstruction: Studies in Contemporary Culture* 14.1 (2014). ISSN: 1547-4348. URL: <https://web.archive.org/web/20150719071422/http://reconstruction.eserver.org/Issues/141/Gazzard.shtml> (visited on 04/14/2018).
- [66] Gijs Gieskes. *gameboy bricks Gameboy classics are often called brick or brick-boy because they...* 2006. URL: [http://gieskes.nl/souvenirs/?file=gameboy\\_brick](http://gieskes.nl/souvenirs/?file=gameboy_brick) (visited on 11/05/2018).
- [67] Florent Gorges and Isao Yamazaki. *The History of Nintendo 1980-1991* SC: 2. English. Paris: Les Editions Pix'N Love, Sept. 2012. ISBN: 978-2-918272-35-9.
- [68] Carole Gray and Julian Paul Malins. *Research procedures/methodology for artists & designers*. en. Report. Centre for Research in Art & Design, Gray's School of Art, Robert Gordon University., 1993. URL: <https://openair.rgu.ac.uk/handle/10059/640> (visited on 03/31/2015).
- [69] Carole Gray and Julian Malins. *Visualizing research: a guide to the research process in art and design*. OCLC: ocm54537199. Ashgate, 2004. ISBN: 978-0-7546-3577-2.



- [70] Stefano Gualeni. "Self-reflexive videogames: observations and corollaries on virtual worlds as philosophical artifacts." en. In: *G|A|M|E Games as Art, Media, Entertainment* 1.5 (2016). ISSN: 2280-7705. URL: <https://www.gamejournal.it/?p=2903> (visited on 10/07/2018).
- [71] Raiford Guins. *Game After: A Cultural Study of Video Game After-life*. English. Cambridge, Massachusetts: MIT Press, Feb. 2014. ISBN: 978-0-262-01998-9.
- [72] HCG101. *Hardcore Gaming 101: Inventories: Arcades in Video Games*. May 2015. URL: <http://www.hardcoregaming101.net/inventories/arcades2.htm> (visited on 01/01/2017).
- [73] Hernán Sáez and Maximo Balestrini. *NAVE*. 2013. URL: <http://videogamo.com/navearcade/> (visited on 11/26/2018).
- [74] G. Hertz, J. W. Lee, and C. Guevara. "OutRun: Exploring seamless design in the development of an augmented reality art project." In: *2010 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities*. Oct. 2010, pp. 33–38. DOI: [10.1109/ISMAR-AMH.2010.5643298](https://doi.org/10.1109/ISMAR-AMH.2010.5643298).
- [75] Arcade History. *Tecmo World Cup '90 arcade video game by Tecmo (1989)*. arcade-history.com. 2008. URL: <https://www.arcade-history.com/?n=tecmo-world-cup-%2790&page=detail&id=2847> (visited on 02/22/2016).
- [76] IG-88. *Real version of Fix it Felix released last night? [Archive]*. Apr. 2013. URL: <https://forums.arcade-museum.com/archive/index.php/t-271445.html> (visited on 10/29/2019).
- [77] Tom Igoe and Dan O'Sullivan. *Physical Computing: Sensing and Controlling the Physical World with Computers*. Premier Press, May 2004. ISBN: 1-59200-346-X.
- [78] Inconshreveable. *ngrok - secure introspectable tunnels to localhost*. 2018. URL: <https://ngrok.com/> (visited on 11/12/2018).
- [79] Indiegencias. *CONTROL*. Nov. 2013. URL: <https://web.archive.org/web/20150313005919/http://www.elpixelilustre.com/2013/11/control.html> (visited on 07/01/2017).
- [80] Iontank. *The Andy Warhol Museum Amiga Exhibit - Iontank*. en. URL: <https://www.iontank.com/projects/warhol-amiga> (visited on 11/16/2018).
- [81] JAIA. URL: <https://jaia.jp/> (visited on 09/01/2019).
- [82] JAMMA: *Notice of Organisational Change*. June 2012. URL: <https://web.archive.org/web/20120602170936/http://www.jamma.or.jp/> (visited on 09/01/2019).
- [83] JAMMA to JAIA redirect. Apr. 2018. URL: <https://web.archive.org/web/20190426101919/http://www.jamma.or.jp/> (visited on 09/01/2019).

- [84] JAMMA. "TV Game Machine PC Board Unified Standard." In: *Game Machine* 275 (Jan. 1986), pp. 16–17.
- [85] JVS I/O - Pcbotaku wiki. Sept. 2012. URL: [http://wiki.pcbotaku.com/wiki/JVS\\_I/O](http://wiki.pcbotaku.com/wiki/JVS_I/O) (visited on 11/17/2018).
- [86] Dov Jacobson. *Dov Jacobson: Human Vectors* (1982). Aug. 2013. URL: <http://rhizome.org/editorial/2013/aug/1/dov-jacobson-human-vectors-1982/> (visited on 08/01/2013).
- [87] JimAndNathanDoTheGames. *Control - Pressing Buttons Through the Ages - LA Game Space - DoTheGames*. Oct. 2013. URL: <https://youtu.be/e6bdjMATHS0> (visited on 11/08/2018).
- [88] Ken Jordan and Carl Goodman. *GAMEWORLD. Videogames on the Edge of Art, Technology, and Culture*. Puerto de Gijón: Laboral Centro de Arte y Creación Industrial, 2007. ISBN: 978-84-611-5881-2. URL: <http://www.laboralcentrodearte.org/es/files/2007/exposiciones/gameworld-doc/catalogo-gameworld>.
- [89] Jesper Juul. *The Art of Failure: An Essay on the Pain of Playing Video Games*. MIT Press, Mar. 2013. ISBN: 0-262-01905-1.
- [90] Kakujo. *What the Actual Hell? - LA Game Space Experimental Game Pack 01*. Nov. 2013. URL: <https://youtu.be/ckDMNxk8Tvw> (visited on 11/08/2018).
- [91] Kenji Kamiyama. *Fake Food*. Animation, Action, Crime. IMDb ID: tt0804012. Apr. 2004. URL: <http://www.imdb.com/title/tt0804012/> (visited on 08/08/2018).
- [92] Chris Wilkins & Roger M. Kean. *The History of Ocean Software*. 1 edition. Fusion Retro Books, Dec. 2013.
- [93] Kernow. *Beginners Guide To SNK Neo Geo MVS*. Aug. 2012. URL: [https://wiki.arcadeotaku.com/w/Beginners\\_Guide\\_To\\_SNK\\_Neo\\_Geo\\_MVS](https://wiki.arcadeotaku.com/w/Beginners_Guide_To_SNK_Neo_Geo_MVS) (visited on 09/12/2018).
- [94] Aphra Kerr. *The Business and Culture of Digital Games: Game-work And Gameplay*. English. 1 edition. London ; Thousand Oaks, Calif: SAGE Publications Ltd, Mar. 2006. ISBN: 978-1-4129-0047-8.
- [95] Graeme Kirkpatrick. *Aesthetic Theory and the Video Game*. English. 1 edition. Manchester ; New York : New York: Manchester University Press, Aug. 2011. ISBN: 978-0-7190-7718-0.
- [96] Kitty. *Have You Always Wanted to Play "Fix-It Felix Jr." from the Movie "Wreck-It Ralph"? Well Now You Can!* Jan. 2017. URL: [VintageistheNewOld,RetroGamesNews,RetroGaming,RetroComputing](http://VintageistheNewOld,RetroGamesNews,RetroGaming,RetroComputing) (visited on 10/29/2019).

- [97] J. Gary Knowles and Ardra L. Cole, eds. *Handbook of the Arts in Qualitative Research: Perspectives, Methodologies, Examples, and Issues*. English. Los Angeles: SAGE Publications, Inc, Jan. 2008. ISBN: 978-1-4129-0531-2.
- [98] Chris Kohler. *Meet Takahashi-Meijin, Japan's Blazing-Fast Videogame Hero*. Oct. 2008. URL: <http://www.wired.com/2008/10/meet-takahashi/> (visited on 09/27/2015).
- [99] Chris Kohler. *Engineers Restore 1958 'Tennis For Two' Game, Now With Vacuum Tubes | Game|Life | Wired.com*. Dec. 2010. URL: <http://www.wired.com/gamelife/2010/12/tennis-for-two/> (visited on 01/07/2013).
- [100] Yuzo Koshiro. *Talk About Micom Basic Magazine*. Aug. 2019. URL: <https://youtu.be/T5lbX-qk7rY> (visited on 11/03/2019).
- [101] Johan Kotlinski. *Little Sound Dj*. 2013. URL: <http://www.littlesounddj.com/lsd/> (visited on 01/16/2013).
- [102] Johan Kotlinski. *Little Sound Dj v1.0B Operation Manual*. May 2016. URL: [https://www.littlesounddj.com/lsd/latest/documentation/LSDj\\_1\\_0b.pdf](https://www.littlesounddj.com/lsd/latest/documentation/LSDj_1_0b.pdf).
- [103] LLB. *How can demoscene productions be so small?* Aug. 2017. URL: <http://www.ctrl-alt-test.fr/2017/how-can-demoscene-productions-be-so-small/> (visited on 08/29/2018).
- [104] Irken Labs. *Jammafier*. Sept. 2018. URL: <https://irkenlabs.com/jammafier/introduction> (visited on 11/26/2018).
- [105] Matt Leone. *Street Fighter 2: An Oral History | Polygon*. Games Journalism. Mar. 2014. URL: <http://www.polygon.com/a/street-fighter-2-oral-history/chapter-2> (visited on 12/25/2014).
- [106] Jonathan Lessard. "Early Computer Game Genre Preferences (1980-1984)." In: (2015). URL: [http://www.digra.org/wp-content/uploads/digital-library/24\\_Lessard\\_Early-Computer-Game-Genre-Preferences-1980-1984.pdf](http://www.digra.org/wp-content/uploads/digital-library/24_Lessard_Early-Computer-Game-Genre-Preferences-1980-1984.pdf).
- [107] Henry Lowood, Raiford Guins, Mikael Jakobsson, Nick Montfort, and Erkki Huhtamo. *Debugging Game History: A Critical Lexicon*. English. Cambridge, Massachusetts: MIT Press, July 2016. ISBN: 978-0-262-03419-7.
- [108] Nic Lupfer, Bill Hamilton, Andrew Webb, Rhema Linder, Ernest Edmonds, and Andruid Kerne. "The Art.CHI Gallery: An Embodied Iterative Curation Experience." In: *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. CHI EA '15. New York, NY, USA: ACM, 2015, pp. 391–394. ISBN: 978-1-4503-3146-3. DOI: [10.1145/2702613.2725457](https://doi.org/10.1145/2702613.2725457). URL: <http://doi.acm.org/10.1145/2702613.2725457> (visited on 07/01/2017).

- [109] Game Machine. "Board Standardisation by Replacing of TV Game Machine JAMMA Established." In: *Game Machine* 273 (Dec. 1985), p. 4.
- [110] Game Machine. "Convenient Replacement of TV Game Machine Finalised by JAMMA Board Standards Committee." In: *Game Machine* 274 (Dec. 1985), p. 3.
- [111] Game Machine. "TV Machine Board Specification approved at the 28th Board of Directors of JAMMA." In: *Game Machine* 275 (Jan. 1986), p. 12.
- [112] MahakGTR34. *The best MAKs / Superguns - Arcade Otaku*. Jan. 2014. URL: <https://forum.arcadeotaku.com/viewtopic.php?t=26486> (visited on 10/06/2015).
- [113] Jimmy Maher. *The Future Was Here: The Commodore Amiga*. The MIT Press, Apr. 2012. ISBN: 0-262-01720-2.
- [114] Jordan Mallory. *The Analogue CMVS: A \$649 wooden Neo Geo for the gamer who has everything*. en. Nov. 2011. URL: <https://www.engadget.com/2011/11/26/the-analogue-cmvs-a-649-wooden-neo-geo-for-the-gamer-who-has-e/> (visited on 08/21/2015).
- [115] Howard Mandel. "Give Me Shelter." In: *Video Games* 11 (Aug. 1983), p. 17. URL: [https://archive.org/details/Video\\_Games\\_Volume\\_1\\_Number\\_11\\_1983-08\\_Pumpkin\\_Press\\_US/page/n15](https://archive.org/details/Video_Games_Volume_1_Number_11_1983-08_Pumpkin_Press_US/page/n15).
- [116] Lev Manovich. *The Language of New Media*. New Ed. MIT Press, Jan. 2002. ISBN: 0-262-63255-1.
- [117] Victor Marlow and Shaun Holley. *Ten Pence Arcade*. URL: <http://tenpencearcade.co.uk/podcast-31-wonder-boy/>.
- [118] Martin W. *Sega's Plan for World Domination: The Fantasy Factory* (1992). 1992. URL: <https://www.youtube.com/watch?v=hoGyKI5J7k&feature=youtu.be> (visited on 12/17/2018).
- [119] Eva and Franco Mattes. *Colorless, Odorless and Tasteless* (2011). en-US. 2011. URL: <http://0100101110101101.org/colorless-odorless-and-tasteless/> (visited on 11/11/2018).
- [120] Malcolm McClaren. *8-Bit Punk*. Nov. 2003. URL: [http://www.wired.com/about/rss\\_feeds/](http://www.wired.com/about/rss_feeds/) (visited on 09/05/2011).
- [121] Jamie McCormack. *Atari and Ireland*. Nov. 2008. URL: <http://www.gamedevelopers.ie/features/viewfeature.php?article=45> (visited on 12/01/2013).
- [122] Don McCurdy. *Add-ons and helpers for A-Frame VR. Contribute to donmccurdy/aframe-extras development by creating an account on GitHub*. original-date: 2016-02-12T03:33:40Z. Nov. 2018. URL: <https://github.com/donmccurdy/aframe-extras> (visited on 11/26/2018).

- [123] Shaun McNiff. *Art-Based Research*. English. London ; Philadelphia: Jessica Kingsley, Jan. 2009. ISBN: 978-1-85302-621-8.
- [124] Melcadrien's Indie Gaming. *[Loud Noise] Control - Melcadrien's Impressions*. Sept. 2013. URL: <https://youtu.be/oPekE08tVrA> (visited on 11/08/2018).
- [125] Mento. *LA Game Space Round-Up: Part 1*. Sept. 2013. URL: <http://web.archive.org/web/20150221014235/http://www.giantbomb.com/profile/mento/blog/la-game-space-round-up-part-1/103107/> (visited on 11/10/2018).
- [126] MobyGames. *Genre Definitions*. URL: <https://www.mobygames.com/glossary/genres> (visited on 05/07/2015).
- [127] Nick Montfort and Ian Bogost. *Racing the Beam: The Atari Video Computer System*. MIT Press, Feb. 2009. ISBN: 0-262-01257-X.
- [128] David Murphy. "Hacking Public Memory: Understanding the Multiple Arcade Machine Emulator." en. In: *Games and Culture* 8.1 (Jan. 2013), pp. 43-53. ISSN: 1555-4120. DOI: [10.1177/1555412013478687](https://doi.org/10.1177/1555412013478687). URL: <http://journals.sagepub.com/doi/abs/10.1177/1555412013478687> (visited on 08/08/2018).
- [129] Masaya Nakamura. "Business Improvement Request Technology Development." In: *Game Machine* 275 (Jan. 1986), p. 4.
- [130] Takashi Nakamura. *Research Interview with Kōichi Tashiro*. Oct. 2016.
- [131] James Newman. *Best before: videogames, supersession and obsolescence*. Milton Park, Abingdon, Oxon ; New York: Routledge, 2012. ISBN: 978-0-415-57791-5 978-0-415-57792-2 978-0-203-14426-8.
- [132] Jenna Ng, ed. *Understanding Machinima: Essays on Filmmaking in Virtual Worlds*. English. 1 edition. Bloomsbury Academic, July 2013.
- [133] Jakob Nielsen and Hoa Loranger. *Prioritizing Web Usability*. en. Google-Books-ID: YQsje6Ecl4UC. Pearson Education, Apr. 2006. ISBN: 978-0-13-279815-0.
- [134] Nithikul Nimkulrat, Tim O'Riley, and University of Art and Design Helsinki. *Reflections and connections: On the relationship between creative production and academic research*. English. Helsinki: University of Art and Design, 2009. ISBN: 978-951-558-285-0 951-558-285-7.
- [135] Nicolas Nova and Laurent Bolli. *Joypads!: The design of game controllers*. English. 1 edition. CreateSpace Independent Publishing Platform, Aug. 2014. ISBN: 978-1-4973-2349-0.
- [136] Jeannie Novak and Kevin Saunders. *Game Development Essentials: Game Interface Design*. 2nd Revised edition. Delmar Cengage Learning, Apr. 2012. ISBN: 1-111-64288-5.

- [137] Kyle Orland. *MAME devs are cracking open arcade chips to get around DRM*. July 2017. URL: <https://arstechnica.com/gaming/2017/07/mame-devs-are-cracking-open-arcade-chips-to-get-around-drm/> (visited on 07/27/2017).
- [138] Out Of Index Festival. *Out Of Index 2015 live stream*. July 2015. URL: [https://www.youtube.com/watch?v=7jBpB\\_E5sPA](https://www.youtube.com/watch?v=7jBpB_E5sPA) (visited on 08/27/2015).
- [139] PROFILE English JAMMA. Nov. 2018. URL: <https://web.archive.org/web/20181128170651/http://www.jamma.or.jp/english/index.php> (visited on 09/01/2019).
- [140] Gary Penn. "Work In Progress. Rainbow Islands." In: *The One* 6 (Mar. 1989), pp. 14–16.
- [141] Peter. *Control!* Jan. 2014. URL: <https://www.youtube.com/watch?v=dLDSRuRBftA&feature=youtu.be> (visited on 11/08/2018).
- [142] Lizzie Plaugic. *Daniel Rozin's interactive sculpture is made of 832 tiles that respond to movement*. Jan. 2018. URL: <https://www.theverge.com/2018/1/9/16850280/daniel-rozin-interactive-art-interview-video-nespresso-last-chance-to-shine> (visited on 11/12/2018).
- [143] Tamár Polgár. *Freax*. CSW-Verlag, Aug. 2005. ISBN: 3-9810494-0-3.
- [144] Chris Priestman. *The Strange, Cool, Experimental Games Of LA Game Space*. Sept. 2013. URL: [https://web.archive.org/web/20140401035456if\\_/http://www.facebook.com/plugins/like.php?href=http://indiestatik.com/2013/09/17/la-game-space/&layout=button\\_count&show\\_faces=false&width=1000&action=like&font=arial&colorscheme=light&height=21](https://web.archive.org/web/20140401035456if_/http://www.facebook.com/plugins/like.php?href=http://indiestatik.com/2013/09/17/la-game-space/&layout=button_count&show_faces=false&width=1000&action=like&font=arial&colorscheme=light&height=21) (visited on 11/10/2018).
- [145] *Pro Tennis Simulator for Amiga* (1990). URL: <https://www.mobygames.com/game/pro-tennis-simulator> (visited on 09/13/2018).
- [146] Domenico Quaranta. *How to Play Eddo Stern*. Link Editions, 2017. ISBN: 978-0-244-30739-4. URL: [https://issuu.com/linkeditions/docs/eddo\\_stern\\_how\\_to\\_play\\_eddo\\_stern\\_1](https://issuu.com/linkeditions/docs/eddo_stern_how_to_play_eddo_stern_1) (visited on 07/28/2017).
- [147] Tormod & Real. *Video Game Flyers: JAMMA Kit "NEO-GEO" Single Slot, SNK / SNK Playmore Corp*. Mar. 2003. URL: <https://flyers.arcade-museum.com/?page=flyer&db=videodb&id=3465&image=1> (visited on 07/19/2015).
- [148] Sega Retro. *OutRun Europa*. en. 2018. URL: [https://segaretro.org/OutRun\\_Europa](https://segaretro.org/OutRun_Europa) (visited on 06/10/2018).
- [149] Retromaniac. *¡RetroManiac número 9!* July 2014. URL: <http://retromaniacmagazine.blogspot.com.es/2014/07/retromaniac-numero-9.html> (visited on 03/18/2015).



- [150] Brian Richardson. *Use MAME's debugger to reverse engineer and extend old games*. 2017. URL: <http://bzztbomb.com/blog/2013/03/23/use-mames-debugger-to-reverse-engineer-and-extend-old-games/> (visited on 10/29/2019).
- [151] SNK vs. Capcom: SVC Chaos [AES] Prices Neo Geo | Compare Loose, CIB & New Prices. en. July 2019. URL: <https://www.pricecharting.com/game/neo-geo/snk-vs-capcom-svc-chaos-aes> (visited on 07/01/2019).
- [152] Satoshi Sakagami. *My Famicase Exhibition 2014*. 2014. URL: <http://famicase.com/> (visited on 12/19/2018).
- [153] Retro Sanctuary. *Video Game Dithering*. URL: <http://retro-sanctuary.com/comparisons%20-%20differing.html> (visited on 01/24/2013).
- [154] Stephen Scrivener. "Reflection in and on action and practice in creative-production projects in art and design." In: *Working Papers in Art and Design* 1 (2000). ISSN: 14660-4917. URL: [http://www.herts.ac.uk/\\_data/assets/pdf\\_file/0014/12281/WPIAAD\\_voll\\_scrivener.pdf](http://www.herts.ac.uk/_data/assets/pdf_file/0014/12281/WPIAAD_voll_scrivener.pdf).
- [155] Alex Seago and Anthony Dunne. *New methodologies in Art and Design Research: The Object as Discourse*. Royal College of Art, 1997. ISBN: 978-1-874175-56-8.
- [156] Mr Sensible. *OutRun (Game) - Giant Bomb*. Jan. 2019. URL: <https://www.giantbomb.com/outrun/3030-11260/> (visited on 10/29/2019).
- [157] Paul Slocum. *Show #32: Video Game Art 1970-2005*. Oct. 2018. URL: <http://www.andorgallery.com/press32.html> (visited on 12/17/2018).
- [158] Reality Software. *JVS-PAC*. Jan. 2016. URL: <http://jvspac.kirurg.org/> (visited on 11/26/2018).
- [159] Solonface. *LA Game Space Live Stream - Alphabet + Control*. Sept. 2013. URL: <https://youtu.be/uq56UPWiEfE> (visited on 11/08/2018).
- [160] Phil South. "Work In Progress. Forgotten Worlds." In: *The One* 7 (Apr. 1989), pp. 23-36.
- [161] LA Game Space. *CONTROL by Kieran Nolan*. July 2013. URL: <https://www.youtube.com/watch?v=YcL8SvyKtE4> (visited on 07/03/2013).
- [162] Elizabeth Stinson. "Watch: How Andy Warhol's Lost Computer Art Was Finally Found." In: *Wired* (May 2014). ISSN: 1059-1028. URL: <https://www.wired.com/2014/05/watch-andy-warhol-computer-art/> (visited on 11/16/2018).
- [163] Mike Stulir. *Exidy Max-A-Flex System*. 1984. URL: <http://www.classicarcademuseum.org/game-of-the-month/Max-A-Flex.php> (visited on 12/04/2017).

- [164] Superdeadite. *Superguns*. Jan. 2015.
- [165] Melanie Swalwell and Jason Wilson. *The Pleasures of Computer Gaming: Essays on Cultural History, Theory and Aesthetics*. en. McFarland, May 2015. ISBN: 978-0-7864-5120-3.
- [166] John Szczepaniak. *The Untold History of Japanese Game Developers, Volume 2*. Foreword in English and Japanese. OCLC: 890601504. 2015. ISBN: 978-0-9929260-0-7 978-1-5186-5531-9 978-0-9929260-2-1 978-0-9929260-1-4.
- [167] John Szczepaniak. *The untold history of Japanese game developers vol. 3*. English. OCLC: 1057682817. SMG Szczepaniak, 2018. ISBN: 978-0-9929260-8-3.
- [168] MAMEdev Team. *HLSL Effects for Windows — MAME Documentation 0.194 documentation*. 2018. URL: <http://docs.mamedev.org/advanced/hlsl.html> (visited on 07/18/2018).
- [169] MAMEdev Team. *Using the GFX/TileMap viewer (F4) - MAMEDEV Wiki*. 2019. URL: [https://wiki.mamedev.org/index.php/Using\\_the\\_GFX/TileMap\\_viewer\\_\(F4\)](https://wiki.mamedev.org/index.php/Using_the_GFX/TileMap_viewer_(F4)) (visited on 10/29/2019).
- [170] Testmacoroni. *Fix it Felix Jr. - Lode Runner Hack for NES*. 2013. URL: <https://www.zophar.net/hacks/nes/lode-runner/Fix-it-Felix-Jr--855.html> (visited on 10/29/2019).
- [171] *The CPS Changer system*. URL: <http://www.dailyjoystickpodcast.com/retro/the-cps-changer-system/> (visited on 08/17/2014).
- [172] TheOnlyJoey. *Project to reverse engineer and implement a usb hid driver for the JVS arcade protocol: TheOnlyJoey/openjvs*. original-date: 2012-06-08T20:54:52Z. Oct. 2018. URL: <https://github.com/TheOnlyJoey/openjvs> (visited on 11/17/2018).
- [173] TheWzzard. *Ep50: Experimental Game Pack 1 Part: 2*. Oct. 2013. URL: <https://youtu.be/VLm00HUh5Ic> (visited on 11/08/2018).
- [174] Noel Tominak. *The Video Game Industry Learns from the Data Communications Industry*. Aug. 1994. URL: <https://www.mikesarcade.com/cgi-bin/spies.cgi?action=url&type=info&page=JAMMA-origins-paper.txt> (visited on 07/27/2015).
- [175] Harry Tomlomsom. *LA Game Space :: CONTROL*. Nov. 2013. URL: [https://youtu.be/EAMpnYQ\\_VcE](https://youtu.be/EAMpnYQ_VcE) (visited on 11/08/2018).
- [176] VGDensetsu. *Designing 2D graphics in the Japanese industry*. en. URL: <https://vgdensetsu.tumblr.com/post/179656817318/designing-2d-graphics-in-the-japanese-industry> (visited on 11/13/2018).



- [177] Karhulahti Veli-Matti. "Prank, Troll, Gross and Gore: Performance Issues in Esport Live-Streaming." In: *DiGRA/FDG 2016 - Proceedings of the First International Joint Conference of DiGRA and FDG*. Dundee, Scotland: Digital Games Research Association and Society for the Advancement of the Science of Digital Games, Aug. 2016. ISBN: ISSN 2342-9666. URL: [http://www.digra.org/wp-content/uploads/digital-library/paper\\_110.compressed.pdf](http://www.digra.org/wp-content/uploads/digital-library/paper_110.compressed.pdf).
- [178] Chris Wilkins and Roger M. Kean. *The Story of US Gold*. English. 1st edition. Kenilworth: Fusion Retro Books, July 2015. ISBN: 978-0-9931315-3-0.
- [179] Oliver Wittchow. *nanoloop: about*. URL: <https://www.nanoloop.com/about.html> (visited on 02/02/2013).
- [180] Mark J. P. Wolf. *Encyclopedia of Video Games: The Culture, Technology, and Art of Gaming*. en. Google-Books-ID: deBFx7QAwsQC. ABC-CLIO, 2012. ISBN: 978-0-313-37936-9.
- [181] Hiroshi Yoshida. "Games in Games: From Bonus Stages to Virtual Archives." In: IT University of Copenhagen, Nov. 2017.
- [182] Jochen Zurborg. *Pi2Jamma - ArcadeForge*. 2016. URL: <http://arcadeforge.net/Pi2Jamma-Pi2SCART/Pi2Jamma::248.html?MODsId=cb26fe910649baf2492fe922b008112f> (visited on 11/26/2018).
- [183] abatage. *Control: LA Game Space Experimental Game*. Oct. 2013. URL: <https://youtu.be/Ve6n1incCME> (visited on 11/08/2018).
- [184] charcole. *Jamma Video Standard (JVS) IO board implemented using a Teensy 3.1: charcole/TeensyJVS*. original-date: 2015-07-12T20:30:06Z. Nov. 2018. URL: <https://github.com/charcole/TeensyJVS> (visited on 11/17/2018).
- [185] gwEm. *Open Letter to Malcolm McLaren by gwEm*. Apr. 2004. URL: [http://micromusic.net/public\\_letter\\_gwEm.html](http://micromusic.net/public_letter_gwEm.html) (visited on 09/05/2011).
- [186] interactivevisions. *CONTROL (LA/GS game pack 001)*. URL: <https://themetanoias.wordpress.com/2013/07/04/control-lags-game-pack-001/> (visited on 09/01/2015).
- [187] purplecatgamer. *EGPG 2 Control*. Nov. 2013. URL: <https://youtu.be/tIU9ux-Xl4E> (visited on 11/08/2018).

## LUDOGRAPHY

---

Allan Alcorn. (1972). *Pong*. [Arcade], Atari.

Arc Developments. (1989). *Forgotten Worlds*. [Amiga, Atari ST, DOS, C64, CPC, ZX Spectrum], U.S. Gold.

Atari. (1979). *Asteroids*. [Arcade], Atari.

Atari. (1980). *Battlezone*. [Arcade], Atari.

Atari. (1983). *Star Wars*. [Arcade], Atari.

Atari. (1987). *A.P.B.*. [Arcade], Atari.

Atari. (1989). *Gauntlet*. [Macintosh Classic], Mindscape.

Atari. (1990). *Klax*. [Amiga], Tengen.

Atari. (1990). *Klax*. [Arcade], Atari.

Atari. (1996). *San Francisco Rush*. [Arcade], Atari.

Attention To Detail. (1990). *Night Shift*. [Amiga, Atari ST, DOS, C64, CPC, ZX Spectrum], Lucasfilm Games.

Attention To Detail. (1994). *Zool*. [Arcade], Bell Fruit Manufacturing.

Bossa Studios. (2003). *Surgeon Simulator*. [Windows, Linux, OSX, Android, Nintendo Switch, iOS, PlayStation 4], Bossa Studios.

Brøderbund. (1983). *Lode Runner*. [Apple II, C64, Atari 8-Bit], Brøderbund.

Capcom and Dimps. (2016). *Street Fighter V*. [Arcade, PlayStation 4, Windows], Capcom.

Capcom. (1985). *Ghosts 'N Goblins*. [Arcade], Capcom.

Capcom. (1988). *Forgotten Worlds*. [Arcade], Capcom.

Capcom. (1989). *Final Fight*. [Arcade], Capcom.

Capcom. (1991). *Street Fighter II: The World Warrior*. [Arcade], Capcom.

Capcom. (1992). *Final Fight*. [X68000], Capcom.

Capcom. (1992). *Street Fighter II: The World Warrior*. [Super Nintendo / Super Famicom], Hung Hsi Enterprise Taiwan. (1993). *Street Fighter II: Rainbow Edition* (ROM hack). [Arcade], bootleg.

Capcom. (1993). *Street Fighter II: Champion Edition*. [PC Engine], Capcom.

Capcom. (1993). *Street Fighter II: Champion Edition*. [Sharp X68000], Capcom.

Capcom. (1994). *Street Fighter II Turbo: Hyper Fighting*. [Arcade], Capcom.

Capcom. (1995). *Super Street Fighter II Turbo*. [DOS], GameTek, Inc.

Capcom. (1999). *Strider 2*. [Arcade], Capcom.

Capcom. (2010). *Street Fighter IV*. [iOS], Capcom.

Capstone Software. (1992). *Trolls*. [Amiga, C64, DOS], Capstone Software.

CodeMasters. (1986). *BMX Simulator* [C64, Spectrum, Amstrad], CodeMasters.

CodeMasters. (1988). *SAS Combat Simulator*. [C64, CPC, ZX Spectrum], CodeMasters.

CodeMasters. (1989). *Pro Tennis Simulator*. [C64, CPC, ZX Spectrum], CodeMasters.

Cybearg. (2013). *Fix-It Felix Sr.* [Atari 2600], Available online:  
<https://tinyurl.com/fixitfelixsr>

Data East. (1989). *Midnight Resistance*. [Arcade], Ocean Software.

Data East. (1991). *Robocop 2*. [Arcade], Data East.

Disney. (2013). *Fix-It Felix Jr.* [Arcade, Flash, Android, iOS], Disney.

Elite. (1990). *Ghosts 'N Goblins*. [Amiga, Atari ST, DOS, C64, CPC, ZX Spectrum, C16], Elite.

Escape. (1986). *Wonderboy*. [Arcade], Sega.

Future Driver. (2013). *Fix-It Felix Jr. MD*. [Mega Drive / Genesis],

available online: <http://68000.web.fc2.com/felix/index.html>

Graftgold. (1989). *Rainbow Islands*. [Amiga, Atari ST, C64, CPC, ZX Spectrum], Ocean Software Ltd.

Griffin Aerotech. (2015). *Skycursor*. [Arcade], Griffin Aerotech.

Hiroshi Yamauchi and Gunpei Yokoi. (1973). *Laser Clay Shooting System*. [Arcade], Nintendo.

Hudson Soft. (1987). *Shooting Watch*. [Custom handheld], Hudson Soft.

id Software. (1996). *Quake*. [DOS, AmigaOS, Classic Mac OS, Sega Saturn, Nintendo 64, Windows, Linux], GT Interactive.

Image Works. (1987). *Blasteroids*. [C64, Atari ST, Amiga, Spectrum, MSX], Mirrosoft.

IREM. (1984). *Lode Runner*. [Arcade], IREM.

IREM. (1985). *Spelunker*. [Arcade], IREM.

Kee Games. (1974). *Tank*. [Arcade], Atari.

Konami. (1991). *The Simpsons*. [Arcade], Konami.

M2. (2015). *Sega 3D Classics*. [Nintendo 3DS], Sega.

Metalidol. (2013). *Fix-It Felix Jr.* (Lode Runner hack). [NES], available online: <https://www.zophar.net/hacks/nes/lode-runner/Fix-it-Felix-Jr--855.html>

Michael Smith and Dov Jacobson. (1983). *Mike Builds a Shelter*. [Arcade], touring exhibit.

Midway. (1992). *Mortal Kombat*. [Arcade], Midway.

Sega. (1966). *Periscope*. [Arcade], Sega.

Maxis. (2000). *The Sims*. [Windows, Mac OS], Electronic Arts.

Namco. (1979). *Galaxian*. [Arcade], Namco.

Namco. (1981). *Bosconian*. [Arcade], Namco.

Namco. (1983). *Pole Position II*. [Arcade], Namco.

- Namco. (1996). *Namco Museum Volume 1*. [PlayStation], Namco.
- Nintendo Creative Department. (1985). *Super Mario Bros.* [Famicom / NES], Nintendo.
- Nintendo Research and Development 1. (1981). *Donkey Kong*. [Arcade], Nintendo.
- Nintendo Research and Development 1. (1983). *Donkey Kong*. [Famicom / NES], Nintendo.
- Nolan Busnell and Ted Dabney. (1971). *Computer Space*. [Arcade], Nutting Associates.
- Nostalgia. (2014). *Commando Arcade SE*. [C64], available online: <https://csdb.dk/release/?id=137173>
- Nostalgia. (2015). *Ghosts 'N Goblins*. [C64], available online: <https://csdb.dk/release/?id=139257>
- Ocean France. (1991). *Snow Bros.* [Amiga], Ocean Software Ltd (unreleased).
- Ocean Software Ltd. (1988). *Operation Wolf*. [Amiga, Atari ST, C64, CPC, ZX Spectrum], Ocean Software Ltd.
- Ocean Software Ltd. (1989). *Chase HQ*. [ZX Spectrum] Ocean Software Ltd.
- Peter Leipa and Chris Gray. (1984). *Boulder Dash*. [Atari 8-bit], First Star Software.
- Playmore. (2003). *Capcom Vs SNK: SVC Chaos*. [Arcade, Neo Geo AES], Playmore, Capcom.
- Probe Software. (1991). *Out Run Europa*. [Amiga, Atari ST, C64, CPC, ZX Spectrum, Game Gear, Master System], U.S. Gold.
- Ralph Bayer. (1966). *TV Game System*. [Self contained console].
- Sega. (1985). *Fantasy Zone*. [Arcade], Sega.
- Sega. (1985). *Hang On*. [Arcade], Sega.
- Sega. (1985). *Space Harrier*. [Arcade], Sega.
- Sega. (1987). *After Burner II*. [Arcade], Sega.

- Sega. (1987). *Shinobi*. [Arcade], Sega.
- Sega. (1989). *Golden Axe*. [Arcade], Sega.
- Sega AM2. (1986). *Out Run*. [Arcade], Sega.
- Sega AM2. (1990). *G-LOC: Air Battle*. [Arcade], Sega.
- Sega AM2. (1992). *Virtua Racing*. [Arcade], Sega.
- Sega AM2. (1993). *Virtua Fighter*. [Arcade], Sega.
- Sega AM2. (1999). *Shenmue*. [Dreamcast], Sega.
- Sega AM2. (2001). *Shenmue II*. [Dreamcast], Sega.
- Sonic Team. (1991). *Sonic The Hedgehog*. [Sega Mega Drive / Genesis], Sega.
- Special FX. (1990). *Midnight Resistance*. [Amiga, Atari ST, C64, CPC, ZX Spectrum], Ocean Software.
- Steve Russell. (1962). *SpaceWar!* [DEC PDP-1], MIT.
- Taito. (1975). *Gun Fight*. [Arcade], Midway.
- Taito. (1981). *Qix*. [Arcade], Taito.
- Taito. (1987). *Operation Wolf*. [Arcade], Taito.
- Taito. (1987). *Rainbow Islands*. [Arcade], Taito.
- Taito. (1998). *Psychic Force 2012*. [Arcade], Taito.
- Tarn Adams and Zach Adams. (2006). *Dwarf Fortress*. [Windows, OSX, Linux], Bay 12 Games.
- Tecmo. (1989). *World Cup '90*. [Arcade], Tecmo.
- Technōs Japan Corp. (1987). *Double Dragon*, [Arcade], Taito.
- Technōs Japan Corp. (1988). *Double Dragon*, [DOS], Melbourne House.
- Tecnosoft / Sega. (1990). *Thunder force AC*. [Arcade], Sega.

Tecnosoft. (1990). *Thunder Force III*. [Mega Drive], Tecnosoft.

The Bitmap Brothers. (1989). *Xenon 2 Megablast*. [Amiga, ST, DOS], Image Works.

Tiertex. (1989). *Human Killing Machine*. [Amiga, Atari ST, DOS, C64, CPC, ZX Spectrum], U.S. Gold.

Tiertex. (1990). *Strider II*. [Amiga, Atari ST, C64, CPC, ZX Spectrum, Game Gear, Master System, Mega Drive], U.S. Gold.

Tiertex. (1991). *Mercs*. [Amiga, Atari ST, DOS, C64, CPC, ZX Spectrum] U.S. Gold.

Tiertex. (1992). *Street Fighter II: The World Warrior*. [ZX Spectrum], U.S. Gold.

Timothy G. Martin and Micrographic Image. (1983). *Spelunker*. [Atari 8-Bit], Brøderbund.

Toru Iwatani. (1980). *Pac-Man*. [Arcade], Namco.

United Game Artists. (2001). *Rez*. [PlayStation 2, Dreamcast], Sega.

Valve. (1998). *Half Life*. [Windows, PlayStation 2, OSX, Linux], Sierra Studios.

Videogamo. (2012). *NAVE*. [Arcade], touring exhibit.

William Higinbotham. (1958). *Tennis for Two*. [Donner Model 30 analog computer], Brookhaven National Laboratory.

