University of Sussex

Shadows, Touch and Digital Puppeteering

A Media Archaeological Approach

By

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ABSTRACT

Aims

The practical aim of this research project is to create a multi-touch digital puppetry system that simulates shadow theatre environments and translates gestural acts of touch into live and expressive control of virtual shadow figures. The research is focussed on the qualities of movement achievable through the haptics of single and multi-touch control of the digital puppets in the simulation. An associated aim is to create a collaborative environment where multiple performers can control dynamic animation and scenography, and create novel visualisations and narratives.

The conceptual aim is to link traditional and new forms of puppetry seeking cultural significance in the 'remediation' of old forms that avail themselves of new haptic resources and collaborative interfaces.

The thesis evaluates related prior art where traditional worlds of shadow performance meet new media, digital projection and 3D simulation, in order to investigate how changing technical contexts transform the potential of shadows as an expressive medium.

Methodology

The thesis uses cultural analysis of relevant documentary material to contextualise the practical work by relating the media archaeology of 2D puppetry—shadows, shadowgraphs and silhouettes—to landmark work in real-time computer graphics and performance animation. The survey considers the work of puppeteers, animators, computer graphics specialists and media artists.

Through practice and an experimental approach to critical digital creativity, the study provides practical evidence of multiple iterations of controllable physics-based animation delivering

expressive puppet motion through touch and multiuser interaction. Video sequences of puppet movement and written observational analysis document the intangible aspects of animation in performance. Through re-animation of archival shadow puppets, the study presents an emerging artistic media archaeological method. The major element of this method has been the restoration of a collection of Turkish Karagöz Shadow puppets from the Institut International de la Marionnette (Charleville, France) into a playable digital form.

Results

The thesis presents a developing creative and analytical framework for digital shadow puppetry. It proposes a media archaeological method for working creatively with puppet archives that unlock the kinetic and expressive potential of restored figures. The interaction design introduces novel approaches to puppetry control systems—using spring networks—with objects under physics-simulation that demonstrate emergent expressive qualities. The system facilitates a *dance of agency*[1] between puppeteer and digital instrument. The practical elements have produced several software iterations and a tool-kit for generating elegant, nuanced multi-touch shadow puppetry. The study presents accidental discoveries—serendipitous benefits of open-ended practical exploration. For instance: the extensible nature of the control system means novel input—other than touch—can provide exciting potential for accessible user interaction, e.g. with gaze duration and eye direction. The study also identifies limitations including the rate of software change and obsolescence, the scope of physics-based animation and failures of simulation.

Originality/value

The work has historical value in that it documents and begins a media archaeology of digital puppetry, an animated phenomenon of increasing academic and commercial interest. The work is of artistic value providing an interactive approach to making digital performance from

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[1] Following Andrew Pickering, puppetry is 'a temporally extended back-and-forth dance of human and non-human agency in which activity and passivity on both sides are reciprocally intertwined' PICKERING, A. 2010. Material Culture and the Dance of Agency. *In:* BEAUDRY, M. C. & HICKS, D. (eds.) *Oxford Handbook of Material Culture Studies.* Oxford University Press..

archival material in the domain of shadow theatre. The work contributes to the electronic heritage of existing puppetry collections.

The study establishes a survey of digital puppetry, setting a research agenda for future studies. Work may proceed to digitise, rig and create collaborative and web-mediated touch-based motion control systems for 2D *and* 3D puppets. The present study thus provides a solid platform to restore past performances and create new work from old, near forgotten-forms.

Keywords: Studies in Digital Puppetry; Digital Design; Haptics; Performance Animation; Entertainment Technology; Electronic Heritage.

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LIST OF ABBREVIATIONS

ACM	Association for Computing Machinery
API	Application Programming Interface
AR	Augmented Reality
CGI	Computer-Generated Imagery
DCC	Digital Content Creation software
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HID	Human Interface Device
IIM	Institut International de la Marionnette, Ecole Nationale Supérieure des Arts de la Marionnette (ESNAM). 7 place Winston Churchill. 08000 Charleville-Mézières, FRANCE.
NEMA	Network of Experimental Media Archaeology
NPC	Non-Player Character or Non-Playable Character in a videogame
NUI	Natural User Interface
PBA	Physics-Based Animation
SDK	Software Development Kit
SIGCHI	SIGCHI is the Special Interest Group on Computer-Human Interaction of the ACM. They run conferences and publish *Interactions*.
SIGMM	The Special Interest Group on Multimedia of the ACM.

SIGGRAPH	SIGGRAPH is the Special Interest Group on Computer Graphics of the ACM. They organise symposia, conferences, and artistic exhibitions.
UNESCO	United Nations Educational, Scientific and Cultural Organisation. The agency of the United Nations whose purpose it is to promote international collaboration through education, science and culture.
UNIMA	Union Internationale de la Marionnette/ BrUNIMA is the British section of UNIMA, present in 101 countries around the world.
UX	User Experience
VFX	Visual Effects. A collection of techniques for augmenting live action film with digital effects, animation and painting.
VR	Virtual Reality
VGA	Video Graphics Array

GLOSSARY

Affordances	The *affordances* of an object encompass how the design, materiality and technical formation of an object reveal its potential uses. The affordances of a puppet are most interesting given that puppeteering is a creative search for the affordances of an object expanded beyond its original design.
Avars	**A**rticulation **Var**iables: the dynamic numerical controls and groups of controls that configure joints, springs and object properties in an animation 'rig'.
Computer Puppetry	A synonym for ‘digital puppetry’, applied by David Sturman in his article *Computer Puppetry* (1998): "In a computer puppetry system, various devices translate live performers’ body motions into the actions of a computer-generated character. The character appears simultaneously on the video monitor, which lets the performers continually regulate their performance to achieve the desired visual result."
Degrees of Freedom (DOF)	The number of directions an object or joint can move or rotate.
Digital Puppetry	See Computer Puppetry.
Galanty Show	A shadow play or pantomime often produced with

miniature, cut-out figures projected onto a screen or wall. A popular form of 19th Century home entertainment.

Game Engine A development environment that enables the creation of software that uses key features of contemporary video games: 2D/3D graphics, rendering, physics simulation, audio, animation, coding, AI, networking and publishing to multiple platforms. Examples include Unity and Unreal.

Gimbal Lock An artefact, or error, seen in 3D orders of rotation when two planes of rotation become aligned and subsequent rotations seem to jump or glitch.

Humanette Derived from 'marionette', a form of puppetry where a part of the human body forms a major part of the visual image of a figure often augmented with miniature costumes, normally a face but any body part could be used.

Intangible Cultural Heritage ICH means the practices, representations, expressions, knowledge, skills—as well as the instruments, objects, artefacts and cultural spaces associated therewith—that communities, groups and, in some cases, individuals recognise as part of their cultural heritage: Source: https://ich.unesco.org/en/convention.

Interactive Dynamics A computer simulation of physically plausible behaviours in an animation that can be interacted with—in real-time—by a user.

Inverse Kinematics (IK) Describes a set of 'goal-oriented' techniques to calculate the rotations and position of objects structured in a chain, when the position of a goal and root position are known. IK and variations are used in digital animation and robotics.

Iterative Software Design	Involves cycles of prototyping, testing, analysing and refining a solution. The results are fed in to the next cycle of prototype / product refinement.
Kinematic Mapping	The process of assigning properties of human movement as sensed by human interface devices (HID) to corresponding actions and movements in a digital system.
Kinematics	Two senses of kinematics are used: the properties of motion in an object and the mathematical study of 'geometries of motion', including the use of solvers in 2D and 3D software that work out the position of a chain of multi-linked parts, or rig, in orientation to a goal. The digital puppetry system under consideration uses inverse kinematics (IK) and Forward and Backward Reaching Inverse Kinematics (FABRIK).
Machinima	A form of cinematic artistic expression made within video games, or related software, machinima is a real-time production that often involves a dramaturgy, enactment of character and puppetry (character control).
Media Archaeology	A field of study and a research attitude that scrutinises past, dead media with an interest in how old forms are remediated and relate to emerging media. Often discursive and analytical, increasingly Media Archaeology is viewed as an attitude to practical methods in art practice and research.
Motion Capture	A collection of technologies and practices that aim to digitise analogue whole body movement, gestures, hands

and facial expression for processing, analysis and replaying.

Ombromanie Hand shadows.

Open Sound Control (OSC) A communication protocol for networked, real-time control of electronical musical instruments, conputers and other devices designed at UC Berkeley Center for New Music and Audio Technology (CNMAT). It works locally, over wireless networks and over the internet. Beyond sound control, OSC is popular as a general purpose control architecture for multimedia installations and creative tools.

Performance Animation A live application of motion capture, where body, gestures, face and voice action are sensed and used to drive the real-time animation of, usually, a digital character.

Rig and Rigging From a nautical term describing the intricate adjustable support structures made of wood, rope and material, rigging has a similar sense in marionettes (string puppets) and digital animation, where a structure of parts are connected and prepared for animation by defining controls, bones and skin.

Rigid bodies In physics and digital games and 3D, an object that does not deform and has a solid appearance and, probably, a continuous distribution of mass.

Shadow Theatre An ancient form of performance of light, object, shadows, screens, voice and music, traditional shadow puppetry emerged in Asia and persists today in numerous countries. Specific traditions are listed by UNESCO as intangible cultural heritage. Most shadow forms are thought to be threatened by contemporary media and modern life. Contemporary shadow theatre rethought silhouettes and traditional shadows into new configurations through the 19th, 20th and 21st centuries, with experimental interest burgeoning in the mid and late 20th century.

Simulation A computer model of an analogue, real world phenomena.

Soft-body dynamics A field of computer graphics that approaches simulating deformable objects like clothing, fabric, muscles and rubber. Under the influence of other forces, shapes change, may be elastic and collide with itself or other objects:,

Z-fighting Two polygons share the same planar space and rendering artefacts occur, or front-to-back order shifts happen in an unpredictable way. Usually undesirable.

Z-ordering The algorithm to sort and render layers of overlapping on-screen elements (front to back or above to below).

1. INTRODUCTION

□ □ *dianying*: electric shadows

Digital puppetry has a surprisingly long history. Puppetry a longer one.

The work of this thesis aims to devise a model of practice that extends our understanding and notion of the *digital shadow puppet*. It seeks to establish new practical and conceptual relations between the puppet, computation and how puppeteers can express through mediated touch.

There are parallels between puppetry practices and digital contexts that converge into a nexus of interrelated phenomena. The cross-currents between old media forms like shadow puppetry and new media art forms, are very active and traceable. Such remediation demonstrates a basic state of the braiding between old and new media. Puppetry—with all its presumed primitivism—and technology are deeply intertwined.

The present study attempts to communicate the sensorial, phenomenological excitement when puppeteerly movement is created and used expressively in digital contexts. By ‘puppeteerly’ I mean the expressive, skilful, creative manipulation of digital objects with the intent to bring them to life for their audiences

The practical research process focused on the special spirit of animated shadows, silhouettes and remediating traditions of shadow theatre.

1.1 THE PROBLEM

The earliest work undertaken in the context of this thesis had a simple goal and impetus: how can multi-touch technologies be used to puppeteer live, expressive and graceful movement that remediates the expressive range of shadow theatre in a digital, projected environment?

Most existing studies that pertain to the digital remediation of shadow figures encountered at that time had explored imaging and the visuality of shadows, but had not brought live interactive animation into the mix. No studies, at that point, had explored multi-touch interaction as a vehicle for digital shadow puppetry.

The aim of the project was therefore to: specify and make a digital system appropriate to such performance; devise a strategy for how touch, dual-touch, multi-touch and gestural interaction could work; acquire, digitise and create imagery; then iterate, test and evaluate.

The chief practical problem was to create digital design processes and make an interactive digital puppetry system that is thoughtfully attuned to the tactile and gestural acts of puppeteers and enables the performance of expressive movement. Such a system may also serve acts of re-enactment, media preservation and puppet restoration while fulfilling a creative goal of making new forms from old. It is in this sense the work is a media archaeology.

In more detailed terms, the design and making process involves the investigation of such problems as how best to prepare media—digital images or 3D scans of puppets— for movement (known as *rigging*). There is a longstanding problem of how best to map the movements and gestures of touch or the puppeteer's body, to the movement of a digital figure— these are problems of *interaction* and *kinematic mapping*. Designing the visual and kinetic qualities of the simulation also poses practical problems including those arising from software performance and optimisation, coping with software limitations in rendering, and dealing with gaps in a designer's—i.e. my knowledge of coding.

Expressive puppeteering involves a complex inter-relationship, that flows through time, between puppeteer, performing object and audience. The presence of a digital interface to the performing object, tangible or virtual, can be viewed as a problem, analysed below throughout the practical work detailed in *Chapter 3 New Studies*. The experiments explore the live-ness and liveliness of the animated figures in the hands of performer, physics and procedural control. How far does the movement of a digital puppet need to be believable? Are we bound to the pursuit of realism? As most puppetry aims to imitate the vibrancy of life and liveliness, what will be the specific goals and operating principles of our digital simulation? How must we rethink the simulation of liveness when using digital tools?

Further there is a problem of *definition*: while the terms 'puppet' and 'puppetry' are well represented in performance studies, 'digital puppetry' or 'computer puppetry' has generated less scholarly activity. Formally published sources are rare, as documented in the *Chapter 2: State of the Art Review*.

The aims for the project are:

1. To create a digital puppetry tool-kit that can enable real-time control over a simulated shadow theatre environment;
2. To explore a range of shadow puppetry traditions through digital restoration and play;
3. To evaluate the expressive potential of a range of digital interactive methods as forms of puppetry.

1.2 AREAS OF CREATIVE AND CRITICAL ENQUIRY

Over its duration, this project refined the following areas of creative and critical enquiry:

1. What defines a digital puppet? How do the domains of digital puppetry remediate traditional shadow puppetry? I explore the *puppeteerly* in digital modes of performance.
2. How can touch and gestural interaction facilitate expressive puppeteering and collaboration in digital shadow play? I set out to explore the possible modes of control.
3. What are the most effective methods to create and evaluate digital shadow production and play? In what ways can digital processes regenerate and contribute to the creative restoration of archival puppets and figures?

I make an assumption that multi-touch control via a touch-screen of digital shadow puppets, will be *more expressive* than mono-touch, mouse control or other similar methods.

We require a clear description and definition of *expressivity* and the *expressive*.

1.2.1. EXPRESSIVITY

In the domain of interface design for expressive purposes, the organisation and international initiative 'New Instruments for Musical Expression' (NIME)[1] since 2001, have contributed, through conferences and publications, to the discussion of *expressivity* in relation to the creation of new instruments that often explore novel interactions with technology.

Dobrian and Koppelman (2006) elaborate on the 'e' in NIME and begin with a standard Webster dictionary definition:

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[1] NIME: http://www.nime.org

Expression: felicitous or vivid indication or depiction of mood or sentiment; the quality or fact of being expressive[2]

Expressive: effectively conveying meaning or feeling[3]

They acknowledge the fuzziness of the term 'expressivity' and the challenge to come to a workable definition. By making comparisons with other artistic endeavours—making an expressive movement, a sound, drawing a line—they identify a complex process of the encoding of intent through gestural skills and the reading (or decoding) of expression. On drawing and 'reading' the expressive potential of a line: they invite consideration of 'a kinaesthetic sympathy with the hand that drew it—the pressure, the weight, the gestural control':

> "Is the line, then, expressive or does it seem expressive because it is a trace of what I perceive/read as an expressive human action?" (Murata, cited in Dobrian and Koppelman, 2006. pg.278)

They assert instruments in and of themselves are not thought to be expressive but

> "an instrument that enables the player to be expressive" (Dobrian and Koppelman, 2006. pg.278)

In the context of digital puppetry, I use *expressivity* to refer to the *unfolding of potential* though design, sound, voice, movement and animation as mediated by technology. There is a cluster of useful terms and cues, some drawn from musicology and puppetry scholarship, for example,

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[2] Webster Dictionary: https://www.merriam-webster.com/dictionary/expression

[3] Webster Dictionary: https://www.merriam-webster.com/dictionary/expressive

dynamics[4], nuance and grace, that seek to capture the qualities of an instrument in performance and the nexus of interior and exterior relations between performer, object and audience.

Through my projects, I aim to create touch-based control environments that afford sensitive control over the movement, and therefore imitative and communicative potential, of on-screen figures. I wish to create a dynamic where the puppeteer, via touch, can develop methods and skills to feel 'in control' of how a virtual object moves in a simulated system and where the figure itself also contributes emergent aspects that contribute qualities to the performance. It is in this interplay I see a potential 'dance of agency': where handling and learning the performance tool, developing the skills to master its use, amalgamate to create grace and persuasive illusions of movement of animated objects in performance (with varying degrees of success).

The 'expressive' involves the emotional, interactive and perceptual qualities of puppeteerly movement.

In another NIME perspective, Poepel (2005) applies a computational perspective around the encoding and decoding of cues as components of 'emotional expression':

> "Emotional expression plays a key role in musical expression. Performers communicate musical expression to listeners by a process of coding. Listeners receive musical expression by de-coding. Performers code expressive intentions using expressive-related cues... . Extensive work has been done to identify most relevant cues. These cues include tempo, sound level, timing, intonation, articulation, timbre, vibrato, tone attacks, tone decays and pauses." (Poepel, 2005, pg.228)

What are these expressive cues in puppetry? Expressivity in puppetry is about finding an illusion of vitality, of liveliness, through the manipulation of dead objects.

[4] There are numerous types of dynamics: e.g. temporal, visual, sonic.

In the contexts of psychology, expression and music, Daniel Stern (2010) connects a sense of dynamic, expressive cues, to movement and vitality. He decomposes movement (chosen as an example of one expressive aspect central to puppeteering) into five events:

> "[S]tarting with movement, we get five dynamic events linked together. These five theoretically different events—movement, time, force, space, and intention/directionality—taken together give rise to the experience of vitality." (Stern, 2010, p.4)

In a thought experiment exploring dynamic, expressive forms of movement and vitality, Stern (2010) invites us to consider the following words: exploding, surging, accelerating, swelling, bursting, fading, drawn out, disappearing, fleeting, forceful, powerful, weak, cresting, pulsing, tentative, rushing, pulling, pushing, relaxing, languorous, floating, fluttering, effortful, easy, tense, gentle, halting, gliding, swinging, tightly, holding still, loosely, bounding.

Should we interpret how effectively the animation system and puppeteer can achieve such a challenging and nuanced set of movement descriptors? Or, as I prefer, accept that the processes of being 'expressive' are not necessarily open to empirical testing or easy evaluation.

1.3 THE CONTEXTS

1.3.1. BACKGROUND AND EXPERIENCE

My family experience, early education, training and brought me to performance with shadows.

My father spent time in the 1950's in variety, comedy and English pantomime. He accounted stories of trick human shadowgraphs, Lumia and ultraviolet light object performance. As an electrician, he shared his enthusiasm for projection, stage lighting tricks, gauzes and, with my brother (also an electrician), an understanding of lasers and theatre lighting. My father inspired me to performed in pantomime from 1984-1990 when after I continued my studies of Drama and Theatre Studies and majored in Puppetry—a subject I found enthralling and more engaging than text-based actors theatre. The 1990s were a vibrant time for puppetry in the UK. I immersed myself in international puppet theatre at the London International Festival of Theatre (LIFT), the London mime festival and adult puppetry events at the Little Angel Theatre. I viewed a variety of important companies, whose play with light, shadow and multimedia would shape my future pursuits: including:

- Green Ginger (UK);
- Faulty Optic (UK) (I met them on their visit to the Henson Festival of International Puppetry, New York, in 2000);
- Doo Cot: theatre of figures and shadows (UK) with Nenagh Watson;
- Teatro Gioco Vita (Italy);
- La Compagnie Amoros et Augustin (Belgium) and their major production exploring silent film treatment of Zorro using elaborate shadow figures, 'Señor Z'[5];

Between 1996 and 2000, as a lecturer in Modern Drama Studies, I continued my interest in shadow theatre, meeting and interviewing Eugenios Spatharis, the Greek Karaghiozis master puppeteer. I continued practical research, collecting puppet ephemera, books and visual material.

Parallel to all this: I am a product of the 8-bit revolution in home computing in the 1980s: keen on coding, I embraced the role of new and emerging technology in performance. I continued this interest as a Senior Lecturer in Digital Art and Media, including Games and Animation: a site where I could explore the promise of fusing the sensibilities of the puppeteer with live 2D and 3D computer animation.

[5] Amoros et Augustin 'Señor Z': https://www.artsdelamarionnette.eu/audiovisuel/senor-z-par-la-compagnie-amoros-et-augustin/

In pursuit of this study, my scholarly interests led me to archival work in the IIM, in Charleville, viewing material across their video collection, objects and documentation. Eventually, this encounter would lead me to produce the material showcased in Appendix B: Monograph: Karagöz and the ShadowEngine.

I saw video documentation of works by diverse groups from traditional shadow theatres from China, Java, Indonesia, Greece and Turkey and deepened my awareness of critical companies Teatro Gioco Vita and Amoros et Augustin. I viewed the Jim Henson TV series on world puppeteers, including shadow work by Richard Bradshaw (Australia).

At the IIM I researched a wide variety of digital, electronic and robotic projects, scoping the broader field of digital puppetry, that became wider than the scope of the present study. I reviewed early work that fused digital processes of motion capture and puppetry, see in the practice review: Section 2.4.3, eRENA (1999).

1.3.2. A VISUAL MAP OF THE STUDY

A practical investigation into digital shadow theatre is concerned with the overlap between a number of larger fields of study. Within each of those fields, I focus on particular sub-domains that relate to my key areas of enquiry and establish a transdisciplinary scope. The visual map of the Ph.D., in Figure 1, indicates the central focus and the overlap between the contexts that pertain to the investigation.

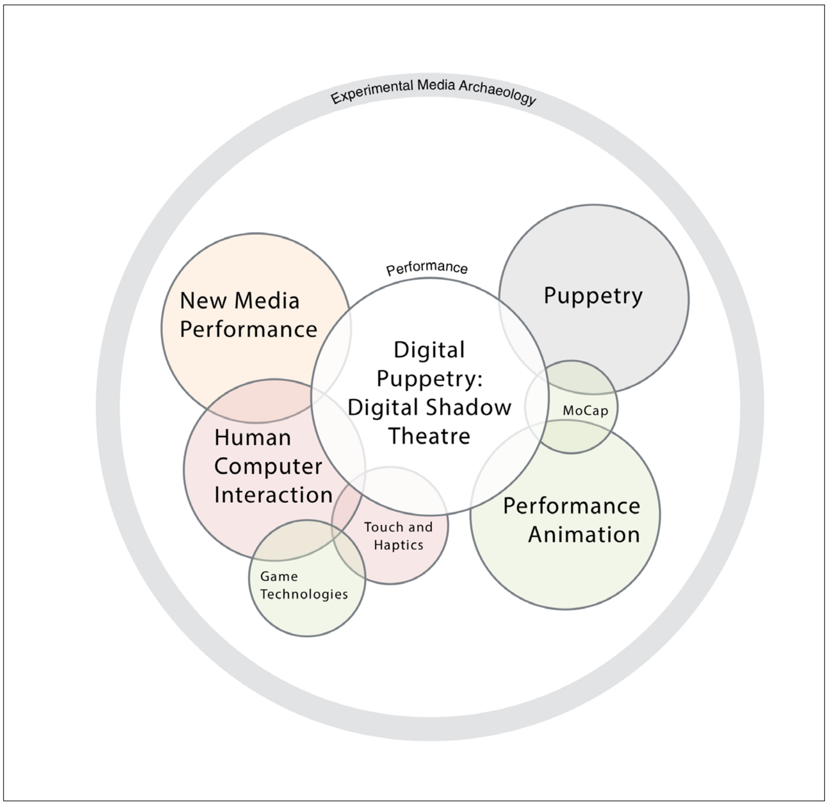

Figure 1: Visual Map of the Ph.D.

1.3.3. DEFINITIONS OF DIGITAL PUPPETRY

One of the key areas of research of this study is *What is a digital puppet*?

There is ongoing debate within computer graphic and puppetry communities about what a digital puppet is.

Here is a list of credible synonyms drawn from the literature: virtual puppet; media figure; screen-based puppet; interactive puppet; computer puppet; techno-puppet; techno-mechanical puppet; electro-magnetic puppet; electronic puppet; electrical puppet; light-puppet, touch puppet; a mo-cap puppet; synthespian; digital make-up; animatronic; audio-animatronic; autonomatronic (an unpronounceable Disney performing robot); avatar; player-controlled character. There may be more.

Are we talking about a single phenomena? Or a curious hybrid formation that has the common goal to create an illusion of life (animus, life-force) with interactive instinct for a spectacular technicity?

I contend the field of digital puppetry should be viewed as older, broader and more inclusive than conventionally defined. The field is regularly presented as emergent and, as we have seen, with a large array of near synonymous terms. The terms *digital*, *computer*, *virtual* or *electronic* puppetry are used almost interchangeably in the field. Each seems to possess useful nuances.

I will evidence an argument for an expanded definition in the discussion of prior art in Ch. 2, below, through the New Studies and Conclusions.

Sturman (1998) offers a definition of computer puppetry:

> "In a computer puppetry system, various devices translate live performers' body motions into the actions of a computer-generated character. The character appears simultaneously on the video monitor, which lets the performers continually regulate their performance to achieve the desired visual result. In some systems, one-to-one correspondence exists between the performer's motions and the character's motions. In other systems, indirect mapping occurs from performer motion to character action." (Sturman, 1998, p.38)

Muller-Arisona (2007) emphasises that digital puppetry is 'live':

> "Digital puppetry, the virtual counterpart of traditional puppetry, deals with manipulation and performance of animated figures and characters. Typically, performance and rendering occurs in *real-time*, which makes digital puppetry distinct from conventional character animation. Also, digital puppetry often includes novel interfaces for expressive control." (Muller-Arisona, 2007)

Levenson emphasises:

> "Technology must not be used to create the puppetry, only to record it. That means that the performance must be at all times under the control of the live, human puppeteer, performing in what computer folks call 'real-time.' This performance is recorded and the recording maybe manipulated (i.e., edited) prior to presentation to the audience." (Levenson cited in Tillis, 1999, p.184)

Levenson's is a conservative definition for a few reasons: The puppet, across all forms, *is* a technology, and its technological material transforms over time. Live-ness and liveliness are important characteristics of the puppet in performance. Puppetry in digital media presents hybrid forms blending both live and recorded expression.

Stephen Kaplin (1994) and Steve Tillis (1999) are important and offer the fullest treatments—to date—of the digital puppet and the definitional challenge 'media figures' present to broader contexts of puppetry studies.

In his definitions, Kaplin (1994) captures multiple facets of what a digital puppet could be. In opposition to Levensen, he is totally accepting of and asserting the fact that technology can be used to create puppets and puppetry:

> Virtual puppetry: "performing objects that exist only within the computer, generated out of digitised bitmaps, given tightly controlled behaviour parameters and linked by manual controls to the outside, human world." (Kaplin cited by Tillis, 1999,p.184-5)

> Docu-puppetry: "'the sampling, cropping and re-editing of media images' and involves the 'depiction in puppet performance of factual and authoritative material, illustrating historical, social or cultural phenomena." (Kaplin cited by Tillis, 1999, p.184)

> Hyper-puppetry: is "a collective extension, a corporate entity [of a computer-generated puppet], created out of the merged energies of [a theoretically 'unlimited' number of] users/participants" (Kaplin cited by Tillis, 1999,p.184) Kaplin adds another term, cyber-puppetry "by which he means networked-

> computer puppetry with an online, 'interactive' dimension that 'allows for the artist to conceive of performances as collaborative creations with the audience." (Kaplin cited by Tillis, 1999, p.185)

I quote these definitions at length as they each describe a facet of the work I persue in the *New Studies*. Through early definitions Kaplin presages practices that intensify as digital technologies and visual effects (VFX) take hold.

So digital puppetry can include a hybrid range of practices including electro-mechanical, mechanical and hybrid combinations of the digital, virtual and physical. In a digital manifestation, digital puppetry refers to the creation of an animated phenomenon that uses *digital* processes as means for sampling control signals from a user / puppeteer (input), to synthesise or actuate movement (actuation) leading to a digitised final representation for display (output). In his relatively early article in the field, Sturman (1998) adds a regulatory feedback loop to this process, signalling that performers iteratively modulate their performance (input) in relation to the display (output). I will discuss this dynamic process further in the conclusions, with close reference to a dance of agency betwixt and between puppeteers and their instruments—an apt metaphor for puppetry with its special interest in simulating vitality.

> "The issue of real-time control seems less of an issue of 'What is a puppet?' than one of 'What is a puppeteer?' a person operating a puppet (tangible or virtual) in real time is palpably doing what puppeteers have always done; but a person working at the keyboard with a virtual puppet—despite the fact that one is controlling the movement of the puppet— does not seem to be engaged in the same activity, despite the fact that the result (i.e., movement of the figure) is the same. This leads us to a paradox: the prospect of puppetry (or of virtual puppetry, at any rate) without recognizable properties. Computers have, one might say, freed the puppet from its dependence on conventional puppeteers." (Tillis, 1999, p.190)

The defintions I've found do not necessarily employ a strict interpretation of the word *digital*. The *digital* is often used synonymously with any advanced technology, whether digital or not. To that end, the terms *digital*, computer, *virtual* or *electronic* puppetry are used almost interchangeably in some literature. The polysemous qualities are due to the ambiguous status of the *materiality* of the digital.

The world of shadow theatre has a deep relation with the virtual that has parallels with the pixels and projections of digital forms. A nuanced philosophical distinction is necessary that accounts for both the material and immaterial properties of shadows.

Digital puppetry, performance animation and motion capture are usefully defined and questioned by early practicioners Brad deGraf and Emre Yimaz in 1999:

> "Performance animation is a new kind of jazz. Also known as digital puppetry or motion capture, it brings characters to life, i.e. 'animates' them, through real-time control of three-dimensional computer renderings, enabled by fast graphics computers, live motion sampling and smart software. It combines the qualities of puppetry, live action, stop motion animation, game intelligence and other forms into an entirely new medium. Being new, the medium is just beginning to be explored, and has created a lot of controversy, driven largely by the perception that it is cheating, the 'Devil's rotoscope,' and is thus somehow not true 'animation.'" (DeGraf and Yilmaz, 1999)

Searls (2014) does a useful task of emphasing that hybridity, innovation and new forms are characteristic of 'traditions of energetic invention' in puppetry. Digital puppetry, visual effects and performance capture (also known as mocap) are examples of new 'harmonious hybrids'.

> "Emerging digital technology has challenged animation and puppetry artists to redraw the boundaries of their crafts." (Searls, 2014,p.295).

Puppetry is a creative media, enlivened and reshaped by new digital forms. This study explores the interaction and tensions between new appropriations of shadow performance and both living and vanishing traditions.

1.3.4. TRADITIONAL, CONTEMPORARY AND DIGITAL SHADOW THEATRE

"Everybody knows what a shadow is." (Reiniger, 1970,p.11)

Through the digital shadow puppetry projects, I wish to operate in an aesthetically informed way, sensitive to and inspired by the cultural and philosophical contexts of traditional and contemporary shadow theatre.

Traditional shadow theatre has many accounts of origin and history According to Chen (2003) the origins are tangled with 'myth, hypotheses, and controversies' (Chen, 2003, p.26). A nomadic tradition, present in China, India, Indonesia, Central Asia, the Middle East and North Africa and, later migrating along the trading routes to Turkey and Greece, shadow theatres take many different forms, aesthetic design, ritual and secular significance, and popularity. There are common elements, including: the presence of a screen, a light source and articulated and non-articulated objects, sometimes opaque sometimes colourised and translucent, used to cast shadows of figures, animals, objects and scenery. Shadow performances often feature spoken or sung story-telling, with music and dance interludes. Performance in some classical traditions (Bali for example) can last two to three hours. Classical repertoires exist and though recorded are viewed as intangible oral cultures.

Puppeteering skills of making, performance and manipulation are often gained via apprenticeships and take years of study to master.

Shadow figures themselves have rich technical and stylistic variety of materials and methods of manufacture. Leather, hide working, paper, cutting, stamping, carving, detailing, balancing, stringing and articulation are all highly skilled elements of the process.

The entry in the World Encyclopedia of Puppetry Arts (Foley and Reusch, 2010) states:

> "The process of making and manipulating requires negative thinking. In designing puppets the cut out part is the most important. What the viewer sees as the white face or the highlighted pattern of clothing is the part of the figure that is missing. Likewise, in [manipulation] clarity and the smallest dimension of the figure come when the figure is close to the screen. As the manipulator pulls the figure back to him/herself toward the light source, the figure fills the screen. While the technique is quickly learned, it remains evocative. What the puppeteer sees as the actuality is in some ways the obverse of what the spectator experiences. Figures can disappear quickly or transformations of one puppet to another happen deftly. This sets up the persistent metaphor of the shadow theatre. The puppeteer sees reality and the audience member experiences maya (illusion)." (Foley and Reusch, 2010)

Shadows, and their theatrical and artistic use, occupy an interesting ground between the tangible and the intangible:

> "The thinnest of puppets, the poorest, the least substantial, is the puppet of shadow theatre - the true puppet here being the moving shadow itself, a thing bound to the screen, whose life is independent of the opaque or translucent silhouette of paper, leather or plastic that casts it. This is puppet all of surface, with no back to it, no depth, or only such hints of depth as are caused by the silhouette's being held closer or farther away from the screen, or with one shadow overlaying or passing through another. It is a shape which, when it fades away, recedes not so much into darkness as into light, always part of something larger than itself, something that shares the nature of what is seen and what is unseen." (Gross, 2012, p.125)

The mid-to-late nineteenth into the early twentieth century saw major challenges to shadow traditions (in Europe and Asia) in the form of cinema and the other myriad examples of mechanised optical play. At the same time Lotte Reiniger, the pioneer of early cinema and stop-motion animation disrupted the new technologies of cinema with a radical re-animation of ancient silhouette forms.

To emphasise that point: Lotte Reiniger, with her love of shadow theatre, and her films that absorb and transform the skills of the shadow puppeteer, is emblematic of the kind of remediation that technological change brings. It is why I spend some time in the *New Studies* analysing and remediating her figures in digital space and animating them with touch (see

Section 3.5.1, and in the video documentation: Video 8, Video 9, Video 12, Video 13, Video 26, and Video 27)

Modernism, electrification, and optics and revolutions in lighting transformed traditional shadow theatre and promoted new visual forms. A multi-fold transformation occurred in shadow theatre in the modern period when innovations in electric lighting introduced new sources of diffused and direct lighting—e.g. incandescent lamps, the halogen (introduced in the USA in 1958), and fluorescent tubes. Where candescent flame would project a crisp image only when the shadow figures were pressed close to the screen, light-sources like halogen lamps provided in-focus shadow edges when figures moved in the space between the screen and light. Reusch (2005) accounts these aesthetic changes and accounts how these technological changes provide a new dimensionality to shadow play and a dynamic morphology as the shadow of an object could dynamically transform its shape:

> "Through the halogen lamp the iron rule of two-dimensionality forced upon the earlier shadow theatre was removed. The third dimension could now be introduced. … A new dynamism could now be achieved and the expressiveness of what was portrayed was greatly increased." (Reusch and Götz, 2013, p.32)

Electric light sources could be mobile and directional. Moveable lighting meant the surface plane of the puppet performance could be transformed in the z-axis and focus—literally—changed the quality of shadows: now a different sense of volume, 3D form and new materials introduced dynamism, vivid colour and a new kind of liveliness.

> "moving the puppet and/or the light source presents the ever-changing silhouettes with an amazingly immense dynamism." (Reusch and Götz, 2013)

Technological advances in illumination seem to down-play the flickering dynamism added to pre-electric shadow theatres in using flame as a light source. Such visual dynamism is, perhaps, something we've forgotten bathed in the steady glow and refresh rates of electric, digital projections.

In the experimental analogue multimedia shadow work of Herta Schönewolf (Germany, late 1960s) seen in Figure 2, below, and documented in her important book "Play with Light and Shadow: Art and Techniques of Shadow Theatre" (1969), we see material exploration, augmented human silhouettes, animated wireframes that find later visual echoes in the audio-visual performance of Sue-C (2013) and Worthington's *Shadow Monsters* (Worthington, 2012). We see dynamic moving screens, shaped screens and a kinaesthetic exploration led by an interest in optical dynamism. Schönewolf's work shares a visual interest in the augmented silhouette and ludic dimension seen in several digital practices presented in Chapter 2, the State of the Art Review.

Late twentieth-century pioneers of contemporary shadows, *Teatro Gioca Vita* led by Fabrizio Montecchi, have an interest in mixed media, blending digital projection and fusing the levels of projection of tangible objects, projected objects and black and white video. Their sense of shadow theatre is dynamic: screens move, lights move, objects move. Performers are often visible in space, are projected upon, and themselves become screens.

Digital shadow theatre is a form of puppetry performance that uses digital technology (all or in part) for the design and crafting of figures, objects, and scenography; the performance, display and projection, and digital capture of puppeteer manipulation and movement.

The chosen modes of human computer interaction (HCI) explored in this project capture movements via the touch and gestures of puppeteers on touch-screens who perform and animate on-screen figures, shapes and scenography.

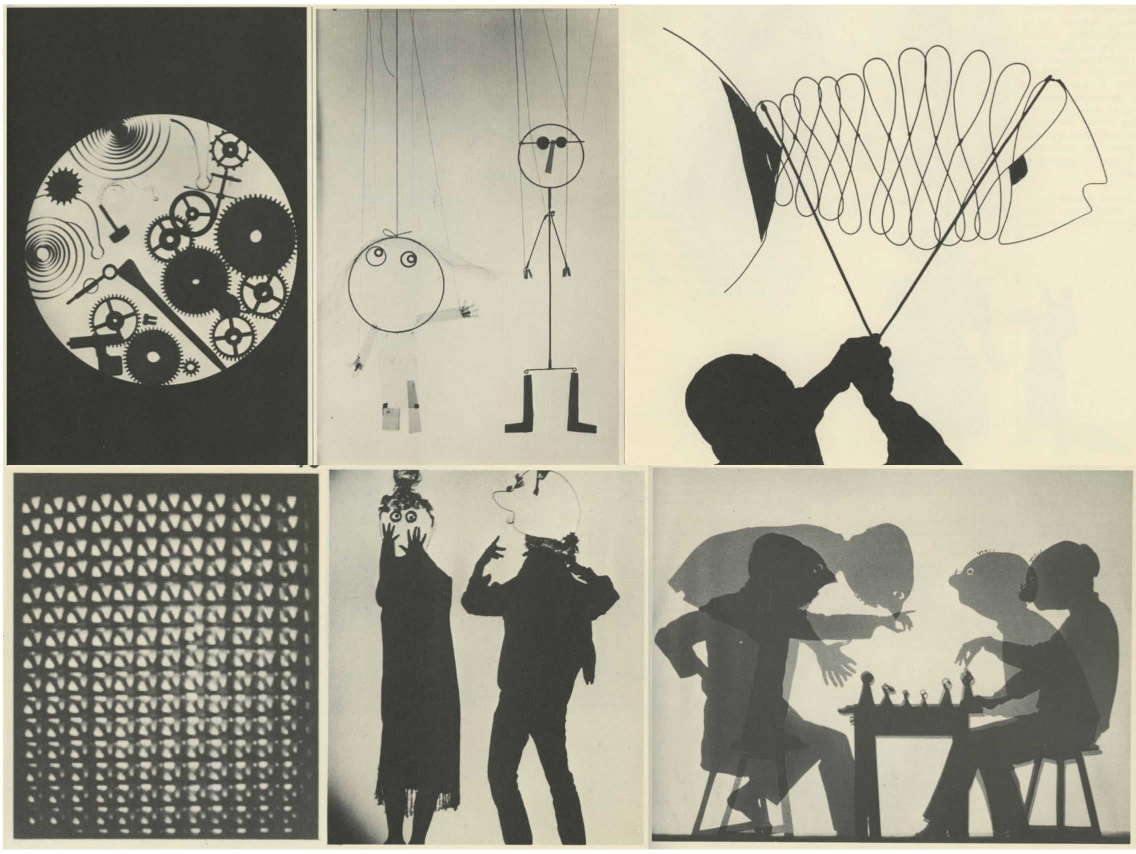

Figure 2: Schönewolf (1969) variety of shadow techniques: physical objects, shaped screens, wire shadow marionettes, material play and physical springs, augmented human shadowgraphs.

The figures are digitally restored from archival sources and are significant in the history of shadow theatre and its remediation. The restoration of old shadow forms in digital ways constitutes a practical experimental media archaeology.

Tillis (1999) makes a point I wholeheartedly believe and think fundamental to the ShadowEngine project:

> "It might be argued that computer graphics figures are not just like, but are the same as, shadow puppets—both being images on a screen—and that therefore

> there are no grounds for distinguishing at all between such figures and puppets. But *contra* this argument, while the shadows in shadow puppetry are indeed only images, the puppets in shadow puppetry are not the shadow images themselves but the tangible puppets—the material entities—that are the direct referents of the shadows. Also it might be argued that computer graphics are just like tangible puppets after all, since they are predicated on the tangibility of the computer screen or the projector screen. But *contra* this argument, neither of these screens is actually the computer graphics figure; they are only the tangible surfaces by which the puppet—which itself has only a virtual 'existence' as a computer code—is made visible" (Tillis, 1999, p.194)

For most of the digital figures in the ShadowEngine, the atoms behind the bits of the projected shadows may be several orders of manipulation and representation removed. Those that involved museum collection scanning and photography, there is tangible referent that is a puppet object. Some of the materials I play with were tangible objects once.

In formal terms—we end up with light: a projection of the image of silhouettes, colours, shape and movement. Potentially as ancient and ritualistic, and is both traditional and experimental practice

> "Shadows are in the first instance evidence only of themselves, of the presence of darkness. It is only when we rethought shadow geometrically as the evidence of objects that shadows became negative, a privation of light. … [Shadows] are neither negations of light nor emanations of darkness but complexly illuminated conjunctures of different modes of light's operation." (Cubitt, 2014,Sec.4.3. Projection)

Digital compositions provide another complex mode for the shadow to inhabit: a mode set to explore the absence of materiality and the occlusion of light with virtual elements: in our case grey-to-black occluding pixels.

1.3.5. DIGITAL PRESERVATION AS A PURPOSE

Most recent studies concerned with digital shadow theatre, as encountered in the literature and practice reviews that follow, in *section 2*, have a preservationist impulse—hoping that *somehow* digital technologies may help traditional cultural practices survive. UNESCO (2017) has inscribed a number of puppetry traditions on the 'Representative List of the Intangible Culture Heritage of Humanity', acknowledging that they are threatened. Added in 2008, such traditions include Wayang puppet theatre from Indonesia; Sbek Thom, the Khmer Shadow theatre from Cambodia; Opera dei Pupi and the Sicilian puppet theatre, from Italy; Ningyo Johruri Bunraku puppet theatre from Japan; In 2009: Karagöz from Turkey. Chinese shadow puppetry was added in 2011 and puppetry from Slovakia and Czechia in 2016.

It is noteworthy that all the shadow traditions on the UNESCO list, with the exception of the Khmer shadow theatre, have all received attention from computer graphics specialists seeking to preserve aspects of the craft—mostly the visual qualities of the figures. Only rarely have these studies focussed on restoring performance or interactive systems, harnessing the skills of puppeteers themselves.

> “The new forms of puppetry will not mean death of traditional forms of puppetry, [but will probably lead them to be] preserved for their historic, spiritual or folkloric value, like endangered species on a game preserve” (Kaplin, 1994,p.39)

Tillis continues this thought:

> “Such preservation does not seem to me like a terribly happy fate; but neither does it seem likely. One is hard pressed to name three traditions of puppetry that have successfully been ‘preserved’ after their audience has deserted them.” (Tillis, 1999,p.193)

Tillis footnotes that Karagöz has effectively disappeared as a popular form, despite the best efforts of the Turkish authorities to sustain it[6].

1.3.6. TOUCH, DIGITAL PUPPETRY AND HUMAN COMPUTER INTERACTION

Touch, Gesture and Digital Puppetry

Human-computer interaction (HCI) is a vast, interdisciplinary and expanding field driven by the need to hone and enrich our relationship with and use of interactive technologies. I am interested when these technologies are used in performance: to capture, mediate and transform movement into animation.

The connection between the HCI fields of touch, gestural and haptic interfaces and puppeteering live animation form a rich subject with sometimes surprising antecedents for my work (discussed in *Ch. 2 State of the Art Review*). For example, we will see the foundational work of Myron Krueger, in section 2.4.1, who in exploration of experiential media art, pioneered in the fields of touch and gestural control. He is widely credited with establishing the gesture of 'two handed pinch to select and manipulate, zoom'—an antecedent of the 'pinch-to-zoom' gesture familiar to users of smart phones and tablets with multi-touch integrated displays.

The language of interaction with touchable devices is still emergent, even unfamiliar, though the devices are increasingly ubiquitous. Consider the terminology of surface based touch and finger level control:

[6] Tillis's essay pre-dates the UNESCO list by 10 years.

1. Mono-touch, mono-point: e.g. computer mice environments have a single pointer with two degrees of freedom—the measurement of distance moved along the x and y axis of a flat surface;

2. Dual-touch: e.g. two fingers touching an image on a display with a pinch-to-zoom, twist-to-rotate gesture has four degrees of freedom: two fingers equals two times two degrees of freedom;

3. Multi-touch, multi-point: true multi-touch gestures exist on popular platforms (Mac trackpads, iPhones, Window 10 touch devices) and are quite esoteric, inconsistent in implementation within a single system and not transparent to discover and use: e.g. three finger tap, three finger swipe, two-finger flick, or three-finger and thumb spread;

4. Dual hand input: on larger touch surfaces and screens, two handed input is possible, enabling collaborative play between multiple operators.

The touching of a tablet (e.g. as manufactured by Wacom [7]) differs from touching a capacitive display or screen. A capacitive touchscreen uses the electrical conductivity of the object touching the screen to track position, such as a finger. Wacom tablets, for example, use electromagnetic resonance technology to detect stylus—not finger—touches and report pressure sensitivity and stylus tilt. Earlier Wacom tablets could support multi-point interactions including a pen and a puck providing different points of user-input – one to draw one to vary line width, for example.

At the time of writing, we are seeing pressure-sensitivity and touch depth emerging as an interactive mode (e.g. with the Apple iPad Pro and Pencil), that may provide an albeit small

[7] See Wacom: https://www.wacom.com/en-ch/enterprise/business-solutions/resources-and-information/emr-benefits [Accessed: 4th May 2018]

additional degree of freedom: but introduce an important point that touch may be a 3D action rather than one locked to a surface.

As we shall see in *Chapter 3 New Studies*, the ShadowEngine explores the use of mono-touch, dual touch, multi-point and multi-touch (e.g. mouse and touch at the same time or the use of two styluses) and gestures.

If 'touch' has multiple definitions in HCI, so does 'gesture'. If we ignore the semantics, i.e. what gestures stand for in a communication system, a useful HCI oriented definition of gesture follows:

> "A gesture is any physical movement that a digital system can sense and respond to without the aid of a traditional pointing device such as a mouse or stylus. A wave, a head nod, a touch, a toe tap, and even a raised eyebrow can be a gesture." (Saffer, 2009, Ch.1.)

As the experience of touch and multi-touch devices spreads and becomes increasingly common, the conventions and language of gestural and touch interaction are still being established:

The interactive approach called 'direct manipulation' coined by Shneiderman (1993 (1981)) is significant in any system that wishes to control physical or virtual objects. Direct manipulation describes methods of using software and computers that use actual touch or the metaphor of touch as a means of interaction. For example, on screen in a GUI, a data object is symbolically represented as an icon of a book and a storage location as a filing folder – the mouse pointer touches/makes contact with the book and drags it to the folder. This is an example of the "windows, icons, menus, pointer" (WIMP) interactions familiar in GUI based computing for decades. However, direct manipulation infers much more than 2D windows based interaction: the tactility of physical objects as input, the direct manipulation of virtual 3D objects with gestures, in the air or on a surface, devices that provide multiple degrees of freedom (DOF) and haptic feedback, become modes of possible interaction and are active areas of research in HCI.

I should briefly mention the related fields of Natural User Interfaces (NUI) and Tangible User Interfaces[8] (TUI). Digital makers and media artists enjoy creating gestural, camera sensed interactive environments, exemplary of natural user interfaces. I consider the use of the Leap Motion and the Kinect, both camera based methods, that create dual hand and whole body interactions. In tangible user interfaces, like we see in Hunter's (2013) puppet based input device, we have hybrid experiments combining aspects of touch, gesture, natural and tangible interaction.

My experiences with large format multi-touch tables/screens that used rear projection for display and camera based computer vision with software to track touch-points, and recognise gestures, marker and 'blobs', first sparked my curiousity in how they could be used for animation and puppetry. I planned an interactive table for the pre-iPad ShadowEngine. It was expensive and the touch tracking inaccurate. In 2010, the iPad launched and, though a smaller playing surface, became my platform of choice to test the concepts of multi-touch collaborative puppetry and animation.

My practical studies encounter several current research themes in touch and human computer interaction, including: kinematic mapping of human movement to screen based objects; the scale of gestures, screens and the virtual space, the control of 3D forms on a 2D surface; and interactive dynamics (using touch in physics based simulations). See Chapter 3 and Chapter 5 for examples and discussion.

[8] See TUIO https://www.tuio.org

1.4 DIGITAL ANALOGUES

When digital processes get involved in the material practices of puppetry, the concept of the 'digital analogue', proposed by Anderson (2006), is particularly relevant. He explains the emergence of:

> "…the 'digital analogue,' a mode that foregrounds material aspects of production seemingly in defiance of the conventional wisdom that digital media are characterized by dematerialization and disconnection from the physical world." (Anderson, 2006, p.1)

In my work, the digital representations of shadow figures are significantly bound to their material counter-parts. The analytical work, performed in digital environments becomes a substitute and an analogue to the work of a puppeteer and maker of tangible objects.

Anderson adds, almost presciently given my interest in the digital shadow:

> "Within the realm of the 'digital analogue,' there is frequently a gravitation toward work that foregrounds the tension between flatness and depth, a kind of resistance to immersion that arguably un-privileges 3-dimensionality." (Anderson, 2006, p.4)

Through transformation, distortion and digital manipulations, we create perceptual nuances that locate the qualities of the shadow puppet in the digital object. How do complex articulations (of the puppet body) make or un-make the digital puppet? I assert through the tangibility of touch and gesture.

Why bring the old forms into digital contexts?

> "No matter how visually similar a digital rendering may be, the perception of that object is radically different to its real world counterpart and it is not

> necessarily possible to translate practices between virtual and real worlds." (Doonan and Boyd, 2008, p.115)

I disagree. Translating puppetry practices from the physical to the digital worlds, helps us re-see qualities of animation, the image, the cinematic, the frame, the screen, the transformed materiality, and gives us renewed old ways of assembling and making motion.

Like Renaud (2002), I argue that contemplating the digital 'avatar' of a shadow figure, does allow a deeper study of the physical mechanism, and can 'discern the finer details of its foundations and uncover its most subtle mechanisms'. To quote in full, Renaud writes:

> "Let us compare the original work and its digital avatar: the former appears as a non-decomposable whole by virtue of the singular force of its 'being- there' (dasein); the latter appears as a decomposable whole or system, whose form, which makes it possible to refer analogically to its model, is by no means intended to provide a copy of that model or to be a servile imitation of it, but rather to discern the finer details of its foundations and uncover its most subtle mechanisms. (Renaud, 2002, p. 15)

1.5 OVERVIEW OF THE THESIS

The thesis consist of five chapters and three appendices:

This *Introduction* summarises the driving critical and creative enquiry and ideas that motivate the practical research into dynamic, touch controlled shadow theatre simulation. It maps the transdisciplinary aspects of the study, introducing digital puppetry, touch and gesture as a method of human computer interaction. It introduces how critical digital practices with a media archaeological attitude informs the methods used and summarises the results.

The *State of the Art Review* expands upon and traces the contexts mapped in *Section 1.3 The Context*. I audit related practical work across media art, puppetry, installation art, and literature from academic and commercial fields emcompassing puppetry studies, computer graphics, and human computer interaction (particularly fields relating to touch and gestural control). I consider work with a direct bearing on digital shadow puppetry, then survey computer art practice and performances where the silhouette is a primary expressive, technical and aesthetic element and where tactility and gestural interaction are foregrounded.

New Studies documents five broad phases of creative development of the ShadowEngine project: from foundation ideas in physics based animation, through the first iterations devising mono-touch to multi-touch puppet control. I establish and refine a digital workflow for figure production. Then the studies apply the workflow to the digital restoration of an archival collection of Karagöz figures and continue developments in performance, puppet manipulation and aesthetic control. After several working prototypes were tested, presented and evaluated, the study focussed on the comparison and analysis of the expressive qualities of figure movement that are created via mono-, dual, and multi-touch interactions. I considered movement across the three rigging and control modes that had been established in the prototypes: dynamic[9] spring networks, direct control and Forward and Backward Reaching Inverse Kinematic (FABRIK) chains. I created a video comparison tool (Appendix A-2) as a method to assist the structured observation and analysis of the videos and resultant movement qualitities.

In the *Conclusions*, I summarise the stand out results from the *New Studies* that contribute to the field and represent contributions to knowledge. I analyse the results with close reference to the critical and creative enquiry. I identify themes that have emerged from the process: some expected, others surprising and emergent. I identify and critique what I value as successful and what I would do differently. There are clear prospects for further development, research, and for deepening the artistic work by means of performance. The preservation and dynamic re-animation of archival shadow figures is successful and engaging, if labour intensive. The touch and gestural control are systematically evaluated and work as a proof of concept, but there are

[9] 'Dynamic' refers to a physics based animation.

identified improvements and other strategies. The *Conclusions* also identify limitations including the rate of software change and obsolescence in the digital space, the scope of physics-based animation and failures of simulation.

The *Appendices* document the creative work and provide examples for the *New Studies*, cross referenced from the main text. This is especially important where a description of a piece of touch puppeteering and animation is better elucidated with the moving image.

Appendix A-1 provides an index list of all the videos presented as documentation of the ShadowEngine and foundation projects. They are cross referenced to Appendix A-3 by page number and hyperlinks. All the videos are indexed with hyperlinked timestamps. In the electronic version of the thesis timestamps directly link to the time in the online video. Offline and in print the timestamps can be either manually looked up in the media archive included with the submission. The offline videos have chapter markers viewable in software such as Apple's Quicktime or VLC[10].

Appendix A-2, the Video Comparison Tool assists in the structured observation of multiple videos each documenting different approaches to touch based digital puppetry control and movement used across the ShadowEngine project.

Multiple videos can be played at the same time, re-ordered to allow side-by-side comparison, and accessed by keyword coded chapter markers. This allows for close, structured observation of movement and the nuanced difference between the same figure rigged in a different way. You can hide the chapter markers to minimise distraction.

The videos included in the tool have been chosen for the following reason. After initial development, I focussed on the expressive and control potential of a range of different techniques: mono-, dual- and multi-touch, the use of simulated physics in spring networks and

[10] VLC https://www.videolan.org/.

hierarchies of controller objects, and different *Inverse Kinematic*(IK) solutions - particularly *Forward and Backward Reaching Inverse Kinematics* (FABRIK), where multiple chains of linked object can interact and create complex yet controllable movement. The coded structured observations are then selected for further thematic analysis and critical commentary in *Chapter 4 Conclusions.*

Appendix A-3 is an annotated list of all the videos in the portfolio of documentation. The annotations are time-stamped, indexing both the content and qualitative observations.

Appendix B is a separate printed monograph containing the photo-documentation of the Karagöz collection at the Institut International de la Marionnette (IIM) and sets it within the context of the broader ShadowEngine project. The media archaeological restoration of the puppet figures allowing movement and touch-controlled performance are represented in select videos in appendix A-3, With the support of a three week research residency and grant from the IIM, I photographed, processed, and 3D modelled a set of Turkish Karagöz figures, tasvirs[11], and stage properties. The IIM hold approximately two-hundred and twenty-two Turkish Karagöz shadow figures, props and sets commissioned by Margaretta Niculescu and made by the puppet maker J. Çelebi (the signature on the figures) for a touring exhibition in 1982.

Appendix C – Code Repositories links to the code repositories of all the main projects discussed in the thesis.

Sections in *New Studies* incorporate selections from the Appendices where the visual, kinetic animations and representation of touch control better demonstrate the interaction with the software.

[11] 'Tasvirs' are objects that are mostly motionless, though some are partially animatable.

1.6 THE METHODS

The puppet is the quintessential dead media: a dead object pretending to be alive. In my work I am looking at how acts of puppetry can be restored from abandoned objects found in archives and documents then performed with and re-mediated with custom digital performance technology.

> "[M]edia archaeology is a way to investigate new media cultures through insights of past new media, often with an emphasis on the forgotten, the quirky, the non-obvious apparatus, practices and interventions. In addition, ... [media archeology] is also a way to analyse the regimes of memory and creative practices in media culture - both theoretical and artistic. Media archaeology sees media cultures as sedimented and layered, a fold of time and materiality where the past might be suddenly discovered anew, and the new technologies grow obsolete increasingly fast." (Parikka, 2012, p.2-3)

The definition of media archaeology, with respect to it being a creative and performative practice as well as a broad and emerging methodology (or as Zielinski would have it an 'activity') is interested in the emergence and historical patterning of techné (craft) and ideas. Media archaeological methods, as far as there are any, can be viewed as a set of very practical techniques that are centred around making. The resultant objects, whether reconstructions of old media, or hybrid imaginary constructs shed light on the multi-layered-ness of how old and new media inter-relate:

> "Experimental media archaeology has an archival drive; it aspires to use the immense collections of media apparatuses (l'appareil de base) waiting in film and other archives for further research." (Fickers and van den Oever, 2013,p.272)

As the work of this thesis progressed, I have had funded research residencies in a major puppet archive and collections, with the aim to do digital reconstructions, see Section 3.7.1 Karagöz and the IIM Collection.

A media archaeological approach offers a re-evaluation of present typologies of puppetry in the contexts of major technological shifts. At once I seek a theoretical, historical (more accurately a media archaeological), a technical and creative-practical orientation to old and new media worlds and puppetry. Of particular interest is the shift in computational and entertainment media and realignments of the view of what puppetry is in the age of digital play and simulation.

The present study works to refine 'media archaeology' as an artistic method of investigation to explore the sensational and expressive aspects of puppetry performance made via and enhanced by the use of computational and interactive technology.

Others have sought to consolidate the field of media archaeology as a set of discrete performable 'methods', rather than a research 'attitude' (Hertz and Parikka, 2012) , but I seek to build upon the relational, the comparative thick descriptions typified in the varied media archaeologies of Zielinski (2010), Kittler (2009), Huhtamo (2000, 2013) and Ernst (2013) and apply the rich discourse and thick descriptive approach to the more-or-less hidden field of computer puppetry.

The digital puppetry field is particularly rich for the media archaeologist as the lived contexts of puppetry have flowed through multiple contexts of remediation, where the contemporary digital/computational contexts are just the latest step in a constant stream of media transformations of analogue things. Puppetry traverses through literature, cinema, opera, television and wider cultural phenomena.

1.6.1. EXPERIMENTAL MEDIA ARCHAEOLOGY

> "Can shadow theatre be an effective bridge between ancient and future performance models?" (Kaplin, 2014 p.96–97)

Through my digital practice and an encounter with old, lost, forgotten shadow figures, I am setting out to create something new.

As a loose artistic method *resurrecting dead media* and media archaeology appeals to me. It aims, to paraphrase Druckrey, not to be reductive or dogmatic but to evolve histories within a larger scheme of reintegration of *technologies, apparatuses, effects, images, [and] iconographies* (Druckrey in Zielinski, 2008, p.ix).

I create my work, which is often simulative, and sometimes involves decontextualising historical puppetry forms, with full knowledge of the necessity for a critical technical practice that seeks to articulate the connections with living, dead and imaginary puppet media while enjoying the liberating sense of technological creative play and making.

An orientation toward experimental media archaeology enables me to explore 'tradition', the *puppet as a technological media object*, and the tacit knowledge and embodied skills involved when we manipulate such media.

> "In offering ... new insights and experiences, experimental media archaeology will inform us about the “tacit knowledge” involved in the use of media technologies and will thereby sensitise us to the role of our senses and our body in the human/machine interaction. This sensorial awareness will re-sensitise the media scholar to the social and cultural inscriptions in the materiality of media technologies beyond the discursive level." (Fickers and van den Oever, 2013, p.277)

I share the positions in the mission statement of *The Network of Experimental Media Archaeology* (NEMA). It outlines out a set of principles that have guided my methodological orientation and seem attuned to thinking about shadows and computer puppetry:

> "Experimental media archaeology is not about creating a reconstruction of an authentic historical experience as accurately as possible. Instead experiments such as re-enactments and simulations are geared to:
>
> creating tacit knowledge and an awareness of the sensorial and experiential dimensions of media use,

> raising the awareness of participants in the experiment about the functionalities ascribed to the materiality of the object;
>
> as well as the symbolic nature of such objects;
>
> the reflective analysis of the performative dimension of technical objects (object as medium);
>
> as well as the critical reflection of the situation dynamics in the experimental space.
>
> (Media Heritage, 2017)

I hope to, tangentially, raise broader cultural and political issues raised by some techno-appropriations of the visual form of lived traditional cultures. As is evident in certain materials—for example, in computer simulations of Turkish, Chinese, Malaysian, Balinese, Indonesian or Greek traditional shadow theatres—digital remediation of past practices happens for a variety of reasons. The traditional practices are—all at once—bound to a sense of tradition and, at the same time, reinvented and transform our memory (actually amnesia) of historical media through a reintegration of form, image and apparatus, with the new.

> "... The notion of resurrecting dead media could prove farcical, futile, or more hopefully, deeply fertile. A broad accounting of the evolution of the apparatus, of the media image, of the history of the media effect, of excavating the embedded intellectual history, and so on, is surely the precursor of what will be an invaluable reconfiguration of a history largely focused on the device and its illusory images. Similarly, the rediscovery of uncommon or singular apparatus, novel and fantastic as they might be, is neither decisive nor fully adequate to formulate an inclusive approach that distinguishes it from connoisseurship, or worse, antiquarianism. Merely reconstituting or retrofitting "old" media into "new" contexts could, in this sense, only emerge as techno-retro-kitsch." (Druckrey in Zielinski, 2008, p.ix)

Though Druckrey warns of the farcical futility of resurrecting old media as a kind of uncreative nostalgia, he also hints at the potential fertility. This fertility is expressed well in Bruce Sterling's

Dead Media Project—it started as a collection of emails to a mailing list seeking to describe, lost, forgotten devices: “media that have died on the barbed wire of technological advance, media that didn't make it, martyred media, dead media.” (Sterling et al., 2015)

One item in Sterling’s master list of Dead Media calls for a reconstruction of Parisian shadow theatre based on a media archaeology of shadow works shown at Le Chat Noir, documented by Cate, et.al (1996)

> “Phillip Dennis Cate’s magisterial treatment of the Chat Noir cabaret’s ‘shadow theatre.’ This is dead media scholarship at its finest! We have a provocative media thesis, which proposes an alternative genealogy for cinema: not in cameras and persistence-of-vision optical toys, but in French black and white silhouette illustration. This impulse moves through drawings, to photomechanical printing, through puppet theatre, and, finally, into a now-forgotten gigantic 20-man media gizmo in the most notorious dive of Bohemian Paris—the Chat Noir ‘theatre of shadows’ of Henri Riviere (1864-1951).” (Sterling et al., 2015, Section Parisian Shadow Theatre)

Sterling proposes a reconstruction that revives the movement suggested by the sequences of still images in the Cate documentation. This fertile suggestion planted the initial connection between a digital shadow theatre that restores movement to book bound documentation of animated shadow theatre and to conceptualise this as a creative media archaeology.

Touch, Proprioception and Embodied Skill

After carefully crafting an object, the work of the puppeteer/maker is to manipulate their object through direct touch, or touch at a distance via control rods, or strings, for example. The distance may vary. Over time, in rehearsal and performance, puppeteer’s embody skill. Touching the material object is central to manipulation in puppetry and the development of performance skills.

> "Tactility is the sensibility of the skin as surface of contact between the perceiving subject and the perceived object. Proprioception folds tactility into the body, enveloping the skin's contact with the world in a dimension of medium depth: between epidermis and viscera. The muscles and ligaments register as conditions of movement what the skin internalises as qualities ... Proprioception translates the exertions and ease of the body's encounters with objects into muscular memory of relationality. This is the cumulative memory of skill, habit, posture." (Massumi, 2002, p.58-59)

Massumi helps us focus in on the sensation of touch as a connection between fingers, the body and object. His description of *proprioception*—our sense of the position and motion of our own body (and, additionally, the objects we hold)—and the role of body-memory as we acquire skill is deeply relevant to the puppeteer.

The work of the puppeteer/maker, after carefully crafting an object, is to manipulate their object through direct touch, or touch at a distance: control rods, or strings, for example. The distance may vary. Over time, in rehearsal and performance, puppeteer's embody skill.

What is pivotal? Is it the clash of practices between so-called analogue and digital puppetry practice? Does one occlude, supplant and out-mode the other? Is there ontological hostility from craft practitioners and puppeteers to the soul-less, de-humanised digital simulations of the digital puppet?

1.6.2. THE PLACE OF PRACTICE

Critical Technical Practice

Creative digital practice in and of itself is not academic research. It certainly involves research processes and the development of insight. The personal discoveries gained through digital craft and making require focus and contextualisation within fields of discourse and rigorous questioning, collection of structured observation, analysis, commentary, and reflection:

Agre (1997b) states:

> “A critical technical practice will, at least for the foreseeable future, require a split identity — one foot planted in the craft work of design and the other foot planted in the reflexive work of critique.” (Agre, 1997b)

Creative practice sits in an awkward but interesting position as both an end and a means.

Alongside playful exploration, it is important to state clear positivist aims, goals and questions while working ‘along a cycle of discovery, planning, testing evaluating and re-planning,’ (Trimingham, 2002, p.59).

Using such iterative cycles of development through my creative process, help account for changes, shifts, unplanned and planned development, and chasing absorbing creative goals. I present the practical projects in a loose chronology: in actuality the projects looped and spiralled to such a point that, finally, the earliest iterations could be revisited and injected with code formed from later insights. In the project, I deliver code and visuals that result from this combinatorial approach. One example of this was finally solving the problem of supporting multi-touch and getting it to work. Getting this to work was indicative of skill development—I could, at last, work effectively in code design and implementation. It was also illuminative of a *process*. Getting it to work was not the primary research outcome. I needed it to work in order to investigate the *process* and evaluate the visual animated results of the system in use.

> “Technical methods do not simply "work" or "fail to work." The picture is always mixed. Every method has its strengths and weaknesses, its elegance and its clumsiness, its subtle patterns of success and failure.” (Agre, 1997a, p.14)

Also, following Agre (1997) a critical technical practice also inverts the core metaphors or underlying philosophies of a field. Within the professional world of puppetry—a wonderful marginal and often marginalised, field—the idea of a digital puppetry practice is itself often viewed with suspicion and excluded as a completely different activity from conventional puppetry.

The very materiality of the puppet as object and the desire for liveness and co-presence are standard expectations in the field.

The skills and practices performed in this study—e.g. coding, animating through touch interfaces—are embodied processes that involve research and cycles of making and reflection: In recognition that presenting those skills without critical commentary and analysis does not constitute academic research, I devised a set of documentation practices. Digital production process were screen captured and made into short videos.

I communicate insights garnered in terms both of my experience as puppeteer: through making, movement and engaging with story and my experience as a creative technologist: coding, configuring and designing. The academic researcher, in pursuit of a doctorate, adds to this experience a reflective and critical dimension.

I expect my ideas and understanding to change:

> "Critical reflection on computer work is reflection upon both its material and semiotic dimensions, both synchronically and historically." (Agre, 1997a, p.15)

The project iterations as documented in *Chapter 3 New Studies* outline the phases of making, early prototypes and propositions, discovery processes and the establishment of cycles of technical goals.

As such the place of practice was not as a unified method nor singular technique, but a quasi improvised process of setting technical goals, establishing creative (critical) process and then placing the work in reflective contexts.

The practice driving this research project has, over an extended period of time, systematically explored the convergence of four major threads of activity:

1. Translation of analogue shadow puppetry manipulation skills to animated digital forms;

2. Digital puppet design and restoration;
3. Creative coding to make expressive touch and multi-touch puppet controllers;
4. Video documentation, observation and analysis of the movement resulting from a variety of interactive approaches;

First and foremost, each phase has explored how digital animated phenomenon exhibit liveliness under a variety of means of puppeteerly control. The kinetic objects and their expressive range is the point of focus throughout each project iteration. Secondly, each project *explores* layers of transition between old and new media—between objects of shadow theatre and their digital simulation, replacement and transformation. This is a media archaeological concern.

The creative journey has moved via discoveries, failures, resisting technical obsolescence, rapid-reiteration and repetition, rapid creation of prototypes and embracing opportunities to follow tangents. The creative digital practice is a set of heuristic methods where method, at times, is applied to the 'madness' only after the fact, post reflection.

Workshopping with Student, Practitioners and the Academic Community

The project proceeded with an idea of open-sourcing its development, ideas and technologies. I initiated user participation with the aim to develop the project and disseminate the work. All code and software for the ShadowEngine are shared publicly on GitHub (see Appendix C – Code Repositories), and the project as a whole is licensed with a creative commons Attribution-NonCommercial-ShareAlike license, promoting redistribution and remixing. The open approach has led to the citation of the work, invitation to present and support requests from students of puppetry in Europe and the USA.

I explored ideas and informally workshopped the ShadowEngine project with students, academics and practitioners in the following institutions, workshops and conferences. Some accelerated the development of the practical material, others the ideas.

Teaching on University level degree courses at the University of West London (2001-2015) in digital art, games development, digital animation and music technology gave opportunities to develop work-in-progress with student and staff groups.

The Creative and Critical Practice Research Group 2012-2014: the University of Sussex had a research group for Creative and Critical Practice (CCPRG). Peers presented and critiqued work in a supportive community of practice.

The following papers presented a mix of demos and emerging ideas:

(2014) "Vital Remediation: The Physical Liveliness of Digital Puppets" Digital Convergences, at the Bournemouth Visual Effects Festival (Bournemouth University)

(2014) "Digital Shadows: Performing Hybrid Shadow Theatre". Merging Media University of Kent: This conference saw the first working demo of multiple iPads controlling the on-screen figures.

(October 2014) A practical demonstration of the ShadowEngine at a shadow theatre workshop with undergraduate Drama and Theatre Studies students at Royal Holloway, University of London. This workshop help to develop the idea to restore 19th-century forms and the critique accelerated the development of a more robust control approach and animation quality.

(October 2014) "Vital Remediation: The Physical Liveliness of Digital Puppets". Digital Convergence. At the Bournemouth Visual Effects Festival, Bournemouth University. October 22-23 2014, UK

(May 2014) "Digital Shadow Play: Depth, Alternative Projections and the Dimension of Shadows" at The Digital in Depth: An Interdisciplinary Symposium on Depth in Digital Media. 30th May 2014. University of Warwick, UK.

(February 2014) "Digital Shadows: Performing Hybrid Shadow Theatre" at Merging Media 2014: An Interdisciplinary Conference on the Study of Hybrid Arts. February 1st 2014. University of Kent, UK.

With Paul McConnell (June 2013) Interactive Technology & the Obsolete Object. Working with and archiving digital creative practice. Paper and Workshop at “Now/Then: Documenting, Publishing and Disseminating Objects & Experiences”, University of Sussex, June 2013. (AHRC funded Postgraduate / Networking / Skills Sharing Symposium).

(2013) "Hacking the Waldo". Presented at the symposium “Puppet Talk Interdisciplinary perspectives on puppets, sounds and objects in performance [public event]”. The University of Sussex, School of Media Film and Music and the School of English.

(2013) "Surfaces and Shadows: Digital Shadow Puppetry and Augmented Silhouette Performance" at the Electronic Visualisation and the Arts conference at the British Computing Society.

(October 2013) “An Introduction to Digital Puppetry: Digital Puppetry and Gesture-Based Control” at the Performing Objects Conference. University, Cornwall, UK. I demoed an early prototype with practitioners, academics, dancers and puppeteers. See Section 3.7, below.

(2013) “Dead Media and the Shadow Puppet”. Presented at the University of Sussex, School of Media Film and Music Doctoral Day, 2013.

(April 2013) "Touch as puppetry: Achieving Subtle and Nuanced Performance Through Tangible Touch Interfaces". Presented at "The Tablet Symposium: Examining new media objects". University of Sussex April 2013

(April 2013) "Resisting obsolescence through hybrid digital practices and pedagogies". Presented at the CAS/CADE Conference: "Codes of Engagement" at the Watershed, Bristol.

(March 2013) "Voice and the Digital Puppet." Presentation at "Puppet Talk Interdisciplinary perspectives on puppets, sounds and objects in performance". University of Sussex.

1.6.3. THE STYLE OF WRITING AND DOCUMENTATION AS SELF-ETHNOGRAPHY

It may be helpful to explain aspects of my writing style and documentation in this thesis.

Appendix B contains some detailed writing and descriptions of Karagöz material derived from my fieldwork at the Institute International Institute de la Marionnette (IIM) in Charleville. The appendix includes my own translations of scene descriptions of Karagöz vignettes, from French, and a short essay that contextualises the photo-documentation in the cultural context of the international museum and Turkish puppetry.

The documentation of the animation projects involved the close observation of screen captured videos taken of me performing with generations of the ShadowEngine system, giving rise to a thick descriptive commentary used as a source for concept generation and theorising that is recorded in Appendix A.

At a point I encountered the creative problem when writing about qualities of movement so decided to systematically comment on video instances of the ShadowEngine system in action. In some cases, the documentation videos are multi-perspective: to present the connection between touching a surface and experiencing the animated visual results. So a viewer can see the hands touching the surfaces and the visual output.

To support this method, I developed a web-based tool (A-2 Video Comparison Tool) to allow the conceptual patterns and coded keywords in the written descriptions to drive further focussed viewing and idea generation from the video material.

The writing in the video documentation appendices has a directness and analytical energy that focusses on qualities of movement and expressive control.

These approaches combine into a method: a broad creative self-ethnographic approach seen through the documentation practices, where close observation of creative output is made textual, coded and reflected upon and used to aid further generation, analysis and synthesis of ideas. These 'discoveries' then inform further investigation in museums (at the IIM researching textual, audio-visual material and objects about contemporary shadow theatre and Karagöz), into creative coding and cycles of making.

Code comments

The self-ethnographic approach is also demonstrated through the comments in the software code. All the code is shared in an online repository, detailed in Appendix C – Code Repositories and accompanies the printed copy of this thesis on a USB key.

The comments have different voices: technical explanation, logs of discovery, memos, notes of joy and exasperation, and account the tentative formation of ideas as the project progressed[12]. I started to get more systematic as the project progressed and strove to use a documentation system where comments could be automatically extracted to narrate the creative development and coding.

1.7 RESULTS

The work offers a number of outcomes: in the form of digital methods, artefacts in the form of software, videos and photographs, and critical analyses that synthesise practical knowledges drawn from puppetry and computational creativity.

Along the way, I have created a digital shadow puppetry system that in seeking beautiful, graceful movement and flow, occasionally found it.

The presented work offers the following contributions to knowledge:

1. A software system which enables touch control, gestural and a variety of other forms of input, to be mapped onto a range of digital shadow figures: characters and props of varying complexity from various world shadow traditions.
2. The software system enables a level of cinematic and sceneographic control that presents a collaborative space for digital storytelling;
3. A puppeteerly approach to animation control that is visual, tactile and collaborative;

[12] Example code comments: https://github.com/iboy/phd_shadowengine_004_2014/blob/51aa7dfd0afa03e568b01eeeb93db46925e9d293/Assets/Scripts/AnimationHandlers.cs

4. An exploration of a variety of control methods using combinations of physics simulation and interactive control;
5. An experimental base for further interactive performance animation experiments expanding traditional forms of shadow puppetry and abstract visual performance;
6. A discussion on the restoration of past puppetry forms and the interplay between old and new. This includes creating an extensive photographed collection of archived Karagöz shadow puppets restored into kinetic play through digital processes involving image preparation and character rigging;
7. A discussion about the expressive potential when puppeteer skills are translated into real-time performance animation.
8. A final succinct summary of the whole: celebrating the work—and the fun of puppeteer engagements with digital media

I assert I've created a valuable starting point for further research. Contemporary interactive technology wishes to change so very quickly. Shadow puppetry, as an ancient form re-surfaces and reminds us that vibrancy comes in enigmatic, deceptively simple forms.

2. STATE OF THE ART REVIEW

2.1 INTRODUCTION

The state of the art review explores the interface between traditional shadow puppetry and tactile and embodied computer technologies. It sets the scene with an audit and discussion of relevant literature: from fields of computing, computer graphics, HCI, puppetry studies, and media art.

Digital puppetry is a relatively undocumented field with no major books surveying the area.

There are many example projects—more than I have space to consider. I select only those that are germane to touch, the visual qualities of shadows and relate to movement.

This review is illustrated with select case studies. I offer an extended definition of the digital puppet, discussing control interfaces, immateriality and the performance presence of the digital performing object.

The present study proposes a media archaeology of 2D and 3D puppetry, and begins that endeavour looking at shadows and their remediation through various technologies: starting with Lotte Reiniger and ending with various new media examples, emphasising those working with augmented silhouettes and performance.

I discuss the rationale of work directly connected to the digital simulation of shadow theatre forms and touch control by Luís Leite aka Grifu (2012, 2016, 2012, 2011)

I select related real-time computer animation work including compositions by media artists Myron Krueger, Luís Leite, Golan Levin, Philip Worthington, Miwa Matreyek, Joon Moon, Design I/O, and others.

Next I identify technical endeavours that aim to simulate shadow figure aesthetics. Most do not consider puppeteering or movement per se, but the preservation of traditions through digital means. Works include Chinese shadows explorations by Li and Hsu (2007), Lam et. al. (2008), Lin et. al. (2013); Chinese shadows paper-cut pattern generation by Li (Li et al., 2007); Wayang kulit (Kelantan form) by Kim and Park, (Kim and Park, 2001) Khor and Chan (2009) and Khor et. al. (2013, 2014, 2015).

2.2 PUPPETRY IN COMPUTING AND HCI

What is it about puppetry that interests technologists?

Sturman (1991, 1998) sets a foundation for Digital Puppetry and performance animation. He provides a historical overview, taking in commercial entities, and summarises a MIT infused academic perspective. Sturman's own Ph.D. explored whole-hand input and 'waldo'[1] glove based real-time control of 3D characters. He describes commercial processes that separate

[1] A Waldo is an armature equipped with sensors (movement transducers) that fits over the human hand and wrist to capture movements typical of a muppet-like mouth puppet. Expressed in a Jim Henson Company patent ROSENBLUTH, S., FORBES, J. S. & MAGILL, T. 2000. *Live performance control of computer graphic characters* [Online]. Google Patents. Available: https://www.google.com/patents/EP1257896B1?cl=en [Accessed 19 Nov 2017].: "A waldo may have a thumb transducer, jaw transducer, palate transducer, up/down movement transducer, left/right movement transducer, and twist transducer. Shoulder, elbow, wrist, and other movements may be accommodated and associated with transducers."

puppeteering and capture from the rendering (image production phase): he considers the computational expense and technical near-possibilities of the period (late 1990s).

Sturman also describes a most puppeteerly attitude: a digital puppetry system fuses the efforts of multiple puppeteers to create the illusion of a single character (1998, p.42). Sturman's work mostly concerns the mapping of puppeteer hand movement to 3D models. Haptics and hand detection is key, puppeteer touch is important in a haptic sense: the puppeteer gets tactile, physical feedback from the device.

The work of Lam et. al. (2008) draws together techniques for real-time simulation of shadow puppets drawn from Javanese traditions. Their work explores using standard OpenGL techniques of texturing, animation, image processing (depth of field blurring), modelling light and procedural algorithms for (automatic) animation. It is primarily interested in simulating the aesthectic qualities of a shadow figure, light and screen.

Figure 3: Lam et. al 2008. A shadow figure and the simulated bloom of light on a screen

From the perspective of performance and puppetry, although real-time image generation techniques were examined, Lam et. al. (2008) describe no real-time performance system. The authors mention the potential for real-time physics simulation in creating expressive animation, but do not develop or propose any techniques for performer-object control, or enlivening the technical demo through performance by puppeteers. The necessity and execution of traditional puppetry skills are removed from the picture.

The Lam paper explores an important and emerging theme I share in my own work, that of preservation of traditional shadow performance and the importance of digital media preserving and promoting cultural heritage.

Kim et.al, (Kim et al., 2006) focus on physics based animation in rigid body simulations of virtual marionettes and empahsise the connection between physically-correct modelling and animation quality. The study concludes that figures with a strong environmental response (e.g. collision and friction) exhibit sophisticated motion. Also, they simulate the physics of joints, controllers and strings, and a 3D figure. They interact with virtual marionette paddles mapped to the movements of two commercial stylus based haptic devices[2] that have six degrees of freedom (DOF). They claim the interactive mode is intuitive, but they seem to replicate the complexity of skill required of a real-world marionetteists who manipulates multiple strings. Kim et.al (2006) establish the idea that interactive control of physics based animation is a rich area in digital puppetry.

Lin et al. (2013) explore how Chinese shadow performance is preserved and augmented through computational techniques. In their *eHeritage*[3] of shadow puppetry project, they derive figure animations from video of shadow puppet performance and use input from facial recognition to generate character profiles and trigger movement in 2D multi-jointed models.

Ghani (2011a, 2011b) explore areas relating to the visualisation and rigging of Wayang Kulit using scripting in Maya. The study establishes an approach to automating digital shadow figure rigging and animation through procedural methods (i.e. through code).

Khengkia Khor (2013) experimented with motion capture to record the motion of both a Wayang Kulit figure (Kelantan) and the movements of the puppeteer. The work is motivated by a preservationist instinct to not only capture the aesthetics of the puppet (Khor attends to the detail of moving light sources), but also digitise the puppeteers movements recognising the embodied aspect of their skill:

> "The digitisation of Wayang Kulit Kelantan will promote the art form and also indirectly help to preserve it in alternative media. One of the major problems

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[2] Two Phantom Omni devices by Sensable Technologies (c1999)

[3] eHeritage:: a neologism conflating Electronic Heritage.

> faced by the traditional Wayang Kulit Kelantan is that of disseminating the technique of puppeteer." (Khor, 2013, p.47)

Though the work was not directly related to touch control, Khor emphasises two digital methods for the production and movement study of simulated shadow performance: (1) split screen documentation: showing puppeteer movement, captured movement alongside the resultant image, and (2) the same alpha-channeled image based 3D modelling techniques I used in the early ShadowEngine work, described in detail in Chapter 3, Section 3.3.1: Acquisition and Image Processing.

Khor's PhD study (2014) establishes the cultural contexts of Wayang Kulit Kelantan and evidences the positive role digitisation and simulation may make in the preservation, accessibility and promotion of the tradition. The image production is very attentive to the stylistics of flame cast shadow theatre including blur, light bloom, shadow area and implied movement, and the colourisation of shadows. One limitation is: the images are constructed in rendered, non-real-time environments (Adobe Photoshop, After Effects Autodesk's Studio Max). He compares the aesthetics of the *real* and *simulated* shadow in terms of static visual appearance and not real-time movement.

As a field, digital puppetry lacks detailed published work that synthesises artistic, academic, computational and commercial endeavors.

There is a strong cluster of research activity, as this review reveals. But minimal work that directly relates to puppeteering concerns.

The majority of digital shadow projects from a computing background focus on the visual appearance of shadow figures and objects, less on the meaning of puppeteering and the important act of making digitisations *move* in the context of performances.

2.3 DIGITAL PUPPETRY PERSPECTIVES

The poetic and aesthetic considerations above raise numerous questions. In digital shadow performance, are we here speaking of the simulation of existing forms or the creation of a new one? How are such concerns explored through a range of experiments within digital shadow puppetry? In the range of work surveyed simulative acts feature. How should they be studied? If, following Cubitt, *every visualisation is a symbol system* (Cubitt, 1998,p.31), we might limit our exploration to digital contexts that simulate the objects, screens and kinetic characteristics of *existing* world shadow puppetry traditions, like the work of Lam et. al. (2008). I assert, however, that we should look further afield to the puppetry experimenters, the animators, sculptors and Lumia artists who form and creatively manipulate actual shadows, and their representations via their re-projected image. We should look at a range of symbol systems and possibilities.

We are trying to grasp the power of the silhouette and the migration of the shadow through contemporary media art, technical demonstration and performance.

I follow the computational perspectives with a discussion from published puppetry scholarship. This draws on two canonical texts regarding virtual and digital puppetry: Kaplin (1999) and Tillis (1999) and some short supplementary material: Flanagan (2004).

The review identifies themes, including: the Cinematics and Kinesthetics of Digital Shadow Play Space; Mimetic Illusionism; 2D Puppet Forms in 3D Digital Space; Performer-to-character Mapping: 2D and 3D (dis)connections; and digitising material culture: kinetic play with heritage objects.

The practice review selects examples of interactive media art with direct relevance to digital shadow puppetry in recognition of contemporaries working in related domains and to acknowledge prior art. Following Janie Geiser (2013), the practice review is focussed on:

> "Work that is engaged in cutting edge art practices, and [are] in deep conversation with our contemporary culture of simulation and mimicry (digital, robotic and otherwise), while embracing the aura of the handmade and hand-operated." (Geiser, 2013)

2.3.1. LUÍS LEITE'S VIRTUAL MARIONETTES (2013-PRESENT)

Luís Leite's *Virtual Marionette* projects currently part of a doctoral study, have their main focus in pedagogy and making puppeteering accessible via novel interfaces, though the various demos have strong performance and installation applications. Seeking a simpler way for children to interact with puppetry, Leite has explored a variety of multimodal interfaces including the Kinect, multi-touch surfaces (the iPad) and the Wii remote.

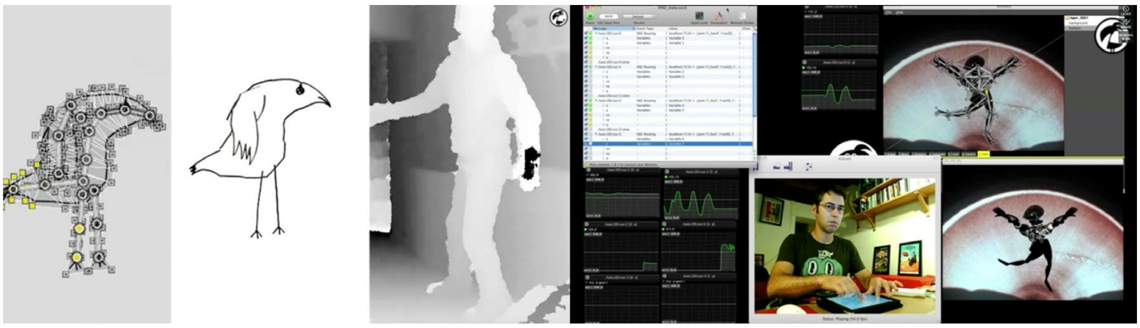

Figure 4: (a) Luís Leite's 'O Pássaro da Alma' using a Kinect (b) Luís Leite's 'IPADATA Project' Multi-touch Shadows

Leite's work is synergetic with mine and we share aesthetic interests in shadow figures and technical methods.

In his multi-touch shadow project IPADATA, illustrated in Figure 4 (b), Leite uses the software *Animata*, the iPad, Apple's Quartz Composer and Open Sound Control (OSC) messages to send multiple touch points to transform the bones of a shadow puppet, assembled in *Animata*.

> "Animata is an open source real-time animation software, designed to create animations, interactive background projections for concerts, theatre and dance performances." (Nemeth et al., 2013)

Animata facilitates the setup of *as-rigid-as-possible shape manipulation* technique (a technique seen in the Jeff Han 2006 demonstration, below) and can also simulate 2D jointed rigid bodies.

Igarashi et.al. (2005) describe the technical algorithims implemented in *Animata* and multi-touch support for animating 2D characters. This is an example of direct manipulation of discrete shapes.

Appendix A-3: Video 46 - Foundations: Animata and Photoshop. Mesh-based image warping tools for real-time animation

The example includes multi-point control of a 2D freeform and bone based deformation using a jointed snake figure from Karagiozis.

Link: https://vimeo.com/249657025

Luís Leite's *O Pássaro da Alma* (Leite and Orvalho, 2012) maps the humanoid skeletal data from OpenNITE (the open Kinect project) to non-human figures. The interest in *indirect* mappings creates a very different style of interface *language* and also presents animation issues. The novel interface language means different control body shapes need to be explored, through play, to discover the characters effective poses and qualities of movement.

Animation issues include over-lapping elements and order-sorting issues, gestural glitches that often leads to physics simulation '*freak-out*'—where the physics constraints and joints between objects fail causing the figure to excessively agitate then explode.

Using a silhouette is a practical convenience as the blackness, the material density, of the shape excludes confusion about the physical reality of the movement and problems like self-occlusion disappear.

Leite's projects exemplify what becomes interesting in whole body interactions where the mechanics of the body are remapped in more-or-less arbitrary ways to the object of animation.

Leite and Lafontana’s recent documentation (Leite and Lafontana, 2016) details a synthesis of several projects into a multimedia ecosystem, where camera and set automation, animation, projection mapping, virtual sets combine to enable “a real-time hybrid performance that fuses theatre with film.” (Leite and Lafontana, 2016, pg.5).

2.3.2. VISIONPLAY: THE FLUID INTERFACES GROUP, MIT (2011)

The VisionPlay framework and project from Seth Hunter and the MIT Fluid Interfaces Group (2013, 2013) explores different methods for integrating physical objects into digital worlds. As a Hasbro fellow, Hunter worked on various methods: green-screen chroma keying, Kinect based motion tracking and Kinect depth-map background substitution. A further method of interest here is Hunter's use of a physical rodded shadow puppet as a physical input device.

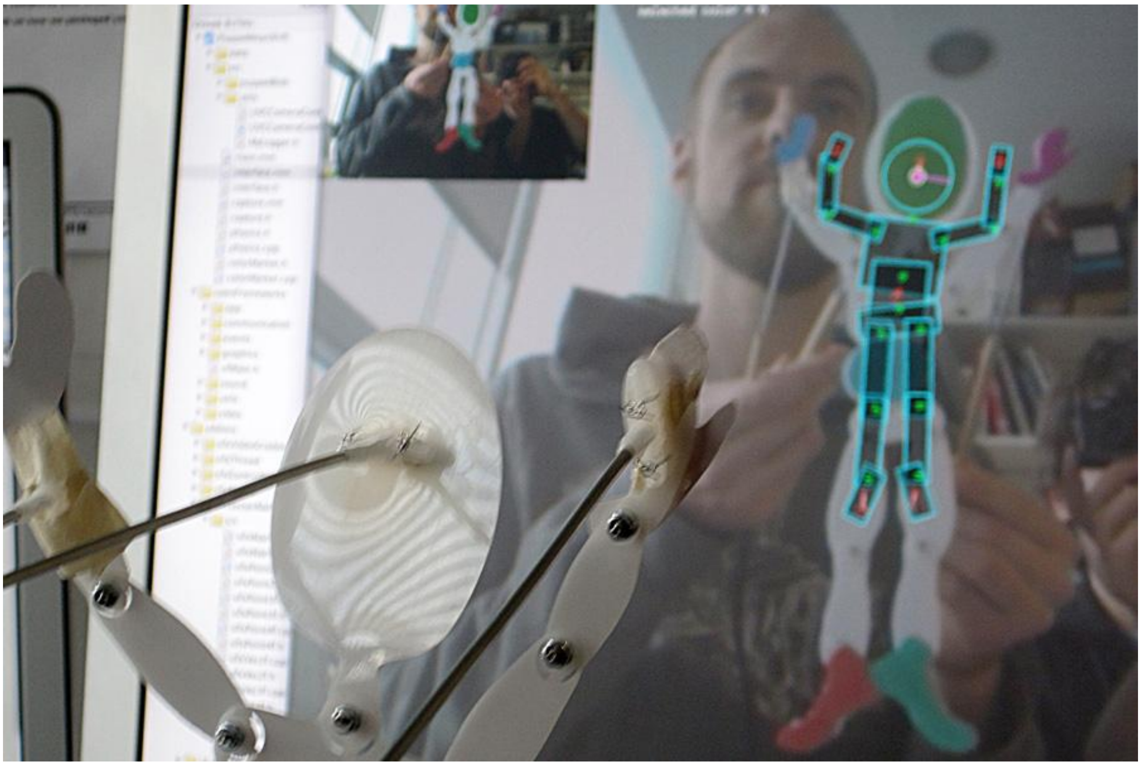

Figure 5: The VisionPlay Framework (2011) from Seth Hunter & the MIT Fluid Interfaces Group

Pictured in Figure 5, above, is an early demo of a real-time on-screen character whose movements are derived by optically tracking a three-rodded shadow puppet, placed on a clear perspex screen. The puppet extremities are recognised via colour recognition routines and the movement of each limb point and head are tracked and mapped onto the virtual puppet, pictured behind the screen. The libraries used to build the system appear to be OpenCV and Box2D within OpenFrameworks.

This example is of particular interest to my thesis as I contend a major part of the attraction of puppetry, in all its forms, are the physical, pendulous movements caused by systems of control fighting gravity, friction and other forces. It is the articulations of the jointed figure at once in control and out of control, the serendipitous movement that brings expressive life to these objects.

The digital puppetry projects of the author, Grant (2003-present) (see Dixon, 2007, Grant, 2008), operate in game engines where numerical simulations of Newtonian physics, spring systems of jointed figures in collision generate motion with emergent qualities. Such calculations can generate input for a variety of purposes, a primary one being to apply the visual results to animated jointed rigid-body objects or created forces in soft-body simulations.

In the MIT VisionPlay project, the physicality of the real object itself provides the necessary qualities of movement, mapped through simple one-to-one mapping to the on-screen kinetic model. Hunter has encountered tracking issues, so the character is also modelled as a dynamic object within a physics engine, Hunter (2013) mentions, to reduce movement blur and to enable the on-screen graphic to collide and interact with other objects within the scene.

Like a classic *dinosaur input device (see Knep et al., 1995),* without the joint sensors, the VisionPlay project enables traditional puppetry skills (and object play) to be explored, making the performance capture intrinsic to the final moving image.

2.3.3. KIM AND PARK “WAYANG” (2001)

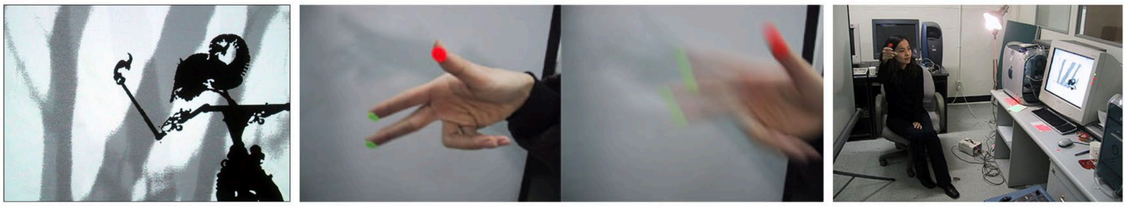

Figure 6: Kim and Park, 2001: "Wayang" - Colour glove tracking gestural interface

Like Hunter (2013), above, Kim and Park (Kim and Park, 2001) use computer vision (the JMyron extension for Macromedia’s Director) to recognise colour markers to provide a gestural input mapped to the joints and limbs of a Wayang figure. Though not centred around touch, I include this as an example where the manual shape and gesture of the hands, the puppeteers tools, are the primary methods of input.

Kim and Park (2001) are worried that processing power and performance do not give them the animation qualities they seek.

2.4 MEDIA ART AND THE SILHOUETTE

2.4.1. MYRON KRUEGER AND VIDEO PLACE (1974)

Myron Krueger and his collaborators with *Video Place*, see Figure 7, below, starting around 1972, designed nearly fifty interactions (or compositions), each playing with the interaction of silhouettes of differing scales, with objects and interventions from other (often distant) spaces.

At once telematic and performative, the system became a technological and aesthetic base-line for future computer vision art installation systems.

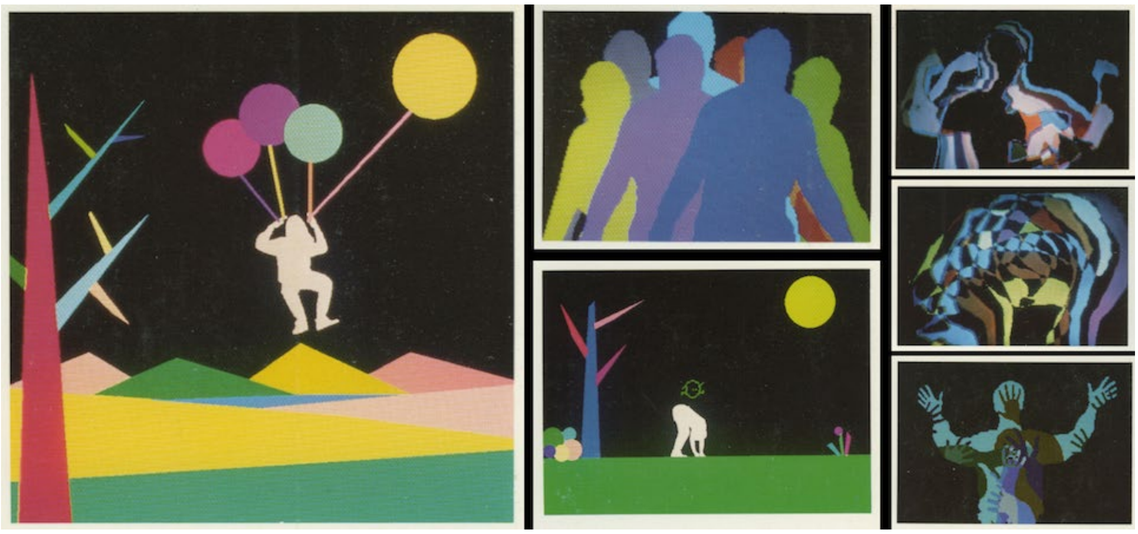

Figure 7: Myron Krueger Video Place (1974)

Krueger (1991) describes the system:

> "Each participant's video image is digitised and is fed to a series of specialist processors that analyses the resulting silhouettes. These processors analyse each image in isolation (e.g. posture, rate of movement) and with respect to graphic objects and live images on the screen. ... When the participant's actions are understood by the specialised processors, they are reported to the executive processor that decides what the responses should be. Depending on the participant's behaviour, it can move an object, change that objects colour, move the participant's image, or make a sound " (Krueger, 1991, p.44–45)

According to Hansen (2006) Krueger's output marks a technical and aesthetic accomplishment, especially in the experience of *action-response synchronicity*:

> "Videoplace, Krueger's interactive platform, marks a further and, in some sense, ultimate, stage in the restoration of autonomy to the responsive environment, understood as encompassing ... the embodied visitor. Videoplace works by capturing an image of the visitor's movement, only in this case the image presents the outline of the visitor's body processed (and distorted in various ways) by the computer." (Hansen, 2006, p.35)

The responsive environments and embodied visitor described by Hansen in the Krueger example constitute features of many of the practical examples developed in this thesis.

In both traditional and contemporary shadow puppetry, the property of *scale* is a subject of play. The scale of the screen, the dynamic scale of the figures, the playful substitutions of scale - the scale of a shadow as we have seen is temporally and spatially dynamic.

> "It is as if evolution has prepared us for seeing ourselves on television screens combined with computer images but also one of the main attractions is the juxtaposition of large and small. So that two people are now interacting and, to some extent discover what the possibilities are and what is suggested emotionally by scale." (Krueger, 2006)

As a pioneer in the artistic and technological fusion of camera sensed interactive art, he established the conceptual space and vocabulary for embodied, creative interactions yet to come.

The presence of the silhouette, scale and transformations are important puppeteerly aspects of Krueger's work. So is touch and gesture. For example: *videotouch* refers to the manipulation of a graphic object by touching it and the special sensation felt when *you touch another person with your image*. Krueger thus anticipated problems still current and germane to digital puppetry, for example: what constitutes true 3D input and how do we overcome the dissociations experienced when finger or whole hand detection is used as input, either *gloved* or not, the latter form being exemplified by multi-touch and the *Leap Motion* hand detection HID launched in 2013.

Krueger also helped establish the dynamics of real-time interaction and, according to Dinkla, promoted the invisibility or the *receding* of the interface:

> "On account of the synchronicity [of the movement of the video image] with the movement of the [visitor's] body it is no longer a question of distinguishing between the activity of the system and the activity of the visitor. The computer system's role as interaction partner fades into the background, and it now makes itself available as an instrument for the visitor to use." (Dinkla cited in Hansen, 2006, p.36)

2.4.2. JEFF HAN AND THE MEME OF MULTI-TOUCH (2006)

Jeff Han, founder of the company *Perceptive Pixel*, stimulated the meme of multi-touch surfaces at a TED talk in 2006 ("Jeff Han demos his breakthrough touchscreen"). Although his demonstrations included two that captured the potential of the technology as an interface for puppeteers, to date there is little evidence of adoption of the technology for puppetry purposes.

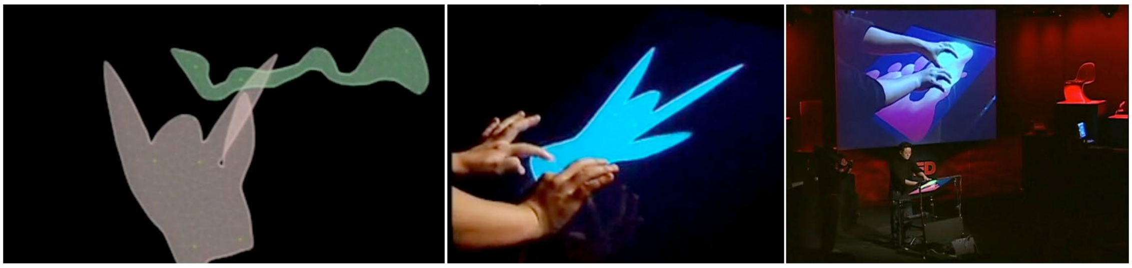

Figure 8: (a) (b) Jeff Han Drawing and Animating 2D Figures with Multi-touch (c) Han adding 'heat' and energy to a fluid simulation with a long-touch (2006)

His commentary, while he draws and animates—see Figure 8 images (a) and (b) above—emphasises the multiple points of manipulation, the connections to 2D puppetry and real-time drawing and mesh deformation routines.

> "I can draw out a curve. And when I close it, it becomes a character. But the neat thing about it is I can add control points. And then what I can do is manipulate them with both of my fingers at the same time. And you notice what it does. It's kind of a puppeteering thing, where I can use as many fingers as I have to draw and make." (Han, 2006)

The other example—see Figure 8 (image c)—less obviously related to puppetry, holds a key to more interesting ways of *controlling* procedural visuals. The touch and haptics illustrated in Figure 8 (image c), the dwell-time, the duration of touch, adds or subtracts *heat* from a 3D fluid simulation, creating a modelling environment and, of interest to the puppeteer, a way of energising *excitations to movement*. Here I'd like to emphasise the move from direct control of screen objects, to another model of *indirect* control. This idea has led me towards an interactive and visual exploration o*f* soft-body simulations as digital shadow puppetry (see Section 3.4.3 Play with Soft-bodies, p.119).

The Jeff Han demo illustrates Woolford et. al's (2010) point that the tech-demo hypes the moment, but frequently doesn't yield critical tools for the performer. With tabletop interaction and popular touch surfaces like the iPad, we do see further exploration of multi-touch puppetry in Grant (2013), Moon (2010), Leite et. al. (2012, 2012, 2013, 2016, 2011)

In recent work, Han demonstrates the networked multi-touch environment. Networked, multi-touch devices are relevant and attractive as puppetry performance is frequently a collaborative act with multiple performers controlling a single figure (in tabletop puppetry (short-rod), or Bunraku) or the necessity for multiple objects or figures to be in play. The latest work of Grant (2013) and Leite (2013) with Unity3D and multiuser networked game environments like *Photon*, multi and second-screen SDKs and protocols like Open Sound Control (OSC) (TouchOSC), facilitates multi-user, multi-touch digital puppetry performance environments.

2.4.3. ERENA (1999)

ERENA, a project part funded by the European Commission, created collaboration seeking 'new forms of cultural experience spanning arts, performance and entertainment.' (CORDIS, 2000). Part of the project explored low-tech pointers to high-tech theatricality, using motion capture, objects and black and white projection, shadows, video, with dancers and puppeters with the IIM and Zentrum für Kunst und Medientechnologie (ZKM)

> "The puppets were manipulated behind one of the rear projection screens, such that the shadows of their physical bodies—and those of their puppeteers' hands and feet—coexisted on the screen with filmed images relayed by the puppet with a camera head. The rear projector light beam conveying the filmed images was

> judiciously employed by the puppeteers, to ensure an indecipherable mix of real shadow and cinematographic projection." (Hirtes et al., 1999,p.21)

> "its layers of ambiguous shadows—some corresponding to physical substance, others technically mediated" (Hirtes et al., 1999,p.21)

It is this acceptance of projection as shadow (without referents), and the hybrid space of mixed projections, multiple screens, and varying scale that form an interesting precedent for the work here. For example, albeit on a smaller scale, see Video 27 and the combination of real and virtual hand represented in the same frame create a similar hybrid image: a new digital ombromanie.

2.4.4. A WORTHERS ORIGINAL: *SHADOW MONSTERS (2004)*

Philip Worthington's *Shadow Monsters* (2004, MOMA 2012), created at the Royal College of Art on the Interaction Design masters programme has seen life as a story-telling project for children, an installation and most recently as an exhibit at the Museum of the Moving Image, New York, where photographer Joseph Holmes took a keen interest in the silhouettes of members of the public, caught mid-interaction—prior to being graphically augmented by the system (See Figure 9, below).

> "Artist Philip Worthington's Shadow Monsters is an interactive project in which visitors were invited to create all kinds of wacky shadow puppets with their bodies in front of an illuminated screen. Through the use of unique code, digital computer augmentation, and light projection, Worthington's installation transformed the simple shadows into lively, projected monsters with fangs, fins, fuzzy ears, googly eyes, and matching sound effects." (Aiello and Gallo, 2013)

Shadow Monsters was created in Processing using the *Myron* computer vision library (a SourceForge project with the aim *to keep computer vision free and easy for the new media* *education and arts community*—named after Myron Krueger)[4]. Sharp silhouettes created against a light-box were videoed. The live video signal was processed: detecting motion, top and lower edges of the arm and top and lower edges of the hand-shape. Random teeth, hair, eyes, fur, fins and spikes were generated and the resultant augmented shadow image re-projected to a screen for the performer and audience to see. Sounds were generated in sympathy with the pace of arm movements and with regard to the *mouth* motion.

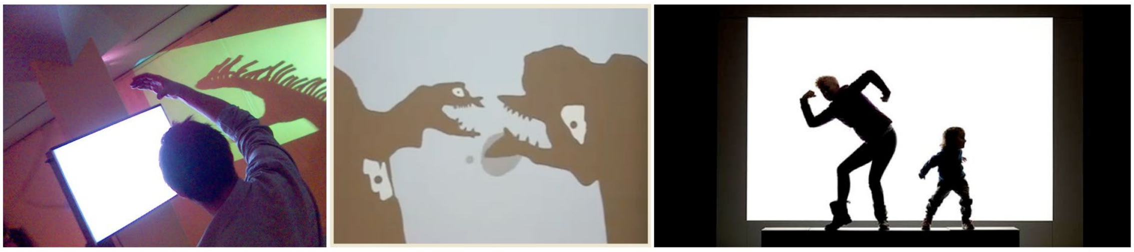

Figure 9: (a) (b): Phil Worthington "Shadow Monsters" (2004-2013) (c) J. Holmes behind the screen photograph

Through many different configurations and iterations of the project, the MOMA exhibit (Figure 9 (c), above) led to a separation (in distance) of the white light-box screen, used to enhance the silhouette and improve the computer vision performance and the screen displaying the augmented image.

> "When photographer Joseph Holmes came upon the exhibit at New York's Museum of Modern Art (MOMA), he wasn't as much interested in the project as he was interested in the hilarious activity that took place in front of the screen. Visitors were inspired to pose playfully in front of the light projections, flexing their muscles, executing dance moves, and even indulging in a quick kiss. As they focused on the screen and the entertaining monsters that their shadows created, their self-awareness faded, and Holmes focused in on these moments, capturing the museum visitors in all of their entertaining gestures and titling the unique photo series Monsters, after Worthington's original project." (Aiello and Gallo, 2013)

4 Myron: Computer Vision for Artists <http://webcamxtra.sourceforge.net/index.shtml>

Stylistically, the augmented images of *Shadow Monsters* echo the physical material play and augmented human shadowgraphs in the theatre of Schönewolf (see Figure 2).

However, the generative graphics and sound forego the tactility and assemblages of object play and lead to a disrupted proprioception[5] for the interactant/performer. The proprioception of the body (of the performer) and the body-in-image when re-projected is an additional peripheral awareness and represents a disconnect. Such a spatial/physical disconnect is familiar to puppeteers. Consider muppeteer Frank Oz operating *Miss Piggy* above his head while watching an external camera view of his own actions on a reverse scan monitor below his feet.

2.4.5. GOLAN LEVIN: COMPUTER VISION FOR ARTISTS

Golan Levin, interactive artist and educator, is producing a range of work that resonates with the field of puppetry including augmented shadowgraphs, sonified shadows, automata and robotic sculptures. Following and building on the legacy of Myron Krueger et. al., his work teaches and popularises computer vision for artists. Computer vision technologies:

1. bring the silhouette to the centre (symbolically) of a range of modalities of interaction, and
2. facilitate (dis)embodied interactive experiences and the whole range of puppeteering like behaviours users, interactants, digital puppeteers have with electronic forms (N.B. not exclusively digital forms).

In Figure 10 (a) we see the *Interstitial Fragment Processor,* one of a range of iterations of an interest in the sonic and visual properties of phenomena Levin refers to as phonesthesia, or

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[5] Proprioception: sensations relating to the self-perception of the position and movement of one's own body. For a puppeteer operating another figure, proprioception becomes an interesting dance between the self awareness of the controlling body shapes and positions and the perception of the image formed with the 'second body' of the puppet.

sound symbolism. In this case, the negative space created by shadows and silhouettes forms elastic shapes that drop under the control of simulated physics and generate sounds on impact with the ground plane and with other spaces.

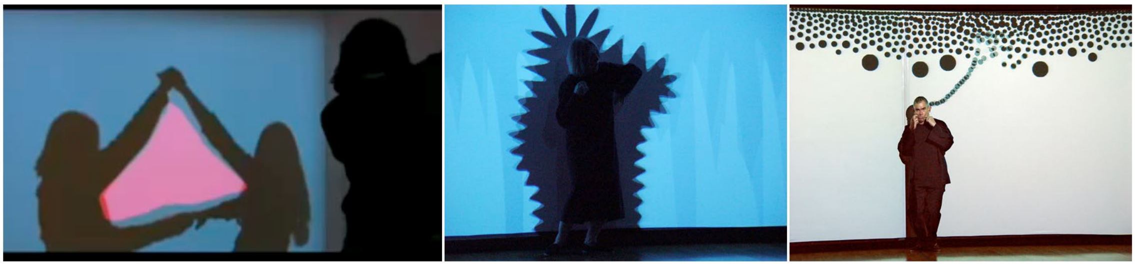

Figure 10: (a) Golan Levin's 'Interstitial Fragment Processor' (2007). (b) (c) Golan Levin et. al (2003). 'Messa Di Voce'

The augmented human shadowgraph is central to the visual space of the installation. Collaborations within and between shadows (and people) are elicited. The game generates shapes that proliferate on the screen.

Levin and Lieberman write:

> "We conclude that our instruments, which merge real-time sound with virtual synthetic graphics and organic analog shadows, enable a new form of live audiovisual cinema to be performed in the hybrid locale of an augmented reality." (Levin and Lieberman, 2005)

In both projects we see a division between play-space, screen and spectator. The player spectates on their own shadow, whilst in the grip of the game and movement (and in the case of *Messa Di Voce*, sonic) improvisations.

Figure 10 (b) and (c) picture two moments from *Messa Di Voce*, the performance (the piece also toured as an interactive installation). The following descriptions from Levin's documentation give a sense of the movement:

Figure 10 (b): Vignette 6: Insect Nature Show:

> "In this module, Joan's silhouette is augmented by an interactive projected shape. This black shape is a larger, bouncier version of her own outline. The edge of this shape, moreover, also changes in response to her speech: it develops wiggles which reflect the timbre and pitch of her voice." (Levin et al., 2004)

Figure 10 (c): Vignette 4: Bounce (Jaap's Solo):

> "A man enters an empty white void. He emits a stream of bubbles by making a special cheek-flapping sound. As his sounds grow more vigorous, his bubbles fill up the screen. But the resulting cloud of jostling sound-bubbles is unstable. Turning to admire his work, his cloud bursts—raining bubbles that, when they fall onto him or crash to the ground below, replay recordings of his cheeky sounds. He tries to contain the noisy torrent, but, failing this, storms off in distress." (Levin and Lieberman, 2004)

There are several moments, particularly where the players play towards the screens rather than the audience, where the technical constraints of camera tracking the performers against a high contrast background over-determine the staging: a bit like watching someone use an iPad, albeit, on a bigger scale. The act of image occlusion by an interactant and subsequent re-direction of audience attention is a problem. The visual illusion, though, of mapping generative augmented shadows, objects, particle systems, placards, to moving performers is effective. Having the penumbra of shadows modulated by sound and voice brings a sensate awareness of the performers to their own shadows (an idea significantly explored in the Worthington's *Shadow Monsters)*.

> "Owing to the head-tracking system, moreover, these visualisations can be projected such that they appear to emerge directly from the performers' mouths. In some of the visualisations, the projected graphical elements not only represent vocal sounds visually, but also serve (bidirectionally) as a playable interactive interface by which the sounds they depict can be re-triggered by the performers." (Levin and Lieberman, 2004)

2.4.6. *AUGMENTED SHADOW* BY JOON MOON AND SU HYUN NAM (2010)

Augmented Shadow is a work by Joon Moon in collaboration with Su Hyun Nam (2010), created using custom software made with OpenFrameworks[6]. Plain cube markers are tracked as they are moved over a tabletop surface. The table-top interface, a common Tangible User Interface Objects-(TUIO) set up[7], has an infrared camera sensor and projector system, within a table-top *screen*. The camera tracks the same screen the projector projects upon from below. The computer vision system can be set to track multiple fingers, patterns, markers or shadows (a.k.a. blobs).

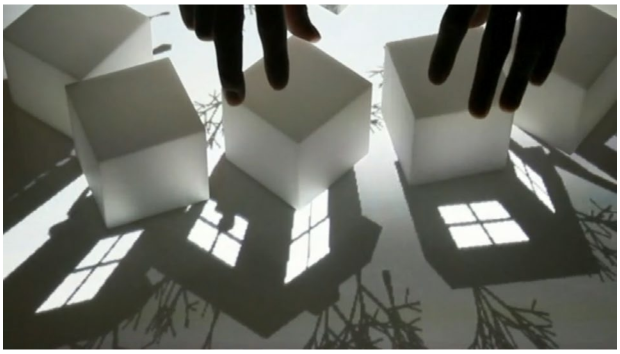

Figure 11: Augmented Shadow by Joon Moon 2010. A figure collects lights and figures in windows. Table-top interface and objects.

Exhibited widely, the piece represents a poetic reconfiguration of the shadow screen. It is an example were the digitally constructed shadow is virtually disengaged from the object, manipulated and reprojected adding levels of interaction, character and narrative. Fabricating a physical impossibility of disengaged shadows is a trope typical in the transformations of shadow

[6] See OpenFrameworks, a creative coding toolkit: http://openframeworks.cc/

[7] See TUIO.org https://www.tuio.org/. It has a useful diagram of a basic table-top setup.

theatre, a metamorphosis usually wrought with trick puppets or quick substitutions. Figure 11 is an illustration of the manipulation mechanism where cube objects are freely moved by users which in turn dynamically effects the animation and shadow-projection. The cubes become proxy puppet controller objects engaging the player into co-creating a dynamic and compelling animated landscape. The manipulations of light and shadow become the interactive properties for the experience:

> "Augmented Shadow is a design experiment producing an artificial shadow effect through the use of tangible objects, blocks, on a displayable tabletop interface. Its goal is to offer a new type of user-experience. … Shadows display below the objects according to the physics of the real world. However, the shadows themselves transform the objects into houses, occupied by shadow creatures." (Moon, 2010)

Animation qualities, a recurrent theme throughout this research, are produced by algorithms controlling movement as birds flock around the cubes and other points of interest. *Augmented Shadow* is a clear example where pre-made animation is *proceduralised* and blended in order to respond to the users interventions.

2.4.7. PUPPET PARADE BY DESIGN I/O

Watson and Gobeille (2011b, 2011a), of Design I/O, after early prototyping with the Kinect and openframeworks, created PuppetParade as a large scale public installation supported by the *Cinekid* festival in the Netherlands. The early prototype mapped the movements of a silhouette of an outstretched arm and hand to the neck and mouth articulations of a 2.5D bird— see Figure 12, below. 2.5D, in this context, being the appearance of 3D forms but locked in a side-on profile.

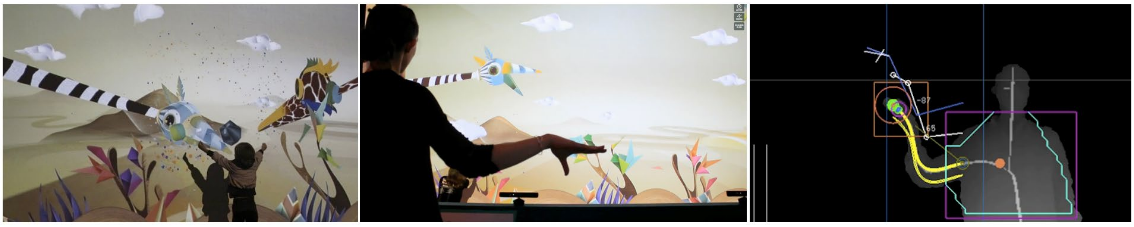

Figure 12: 'Puppet Parade' (a) (b) (c): an interactive installation by Emily Gobeille and Theo Watson (2012)

The computer vision algorithm (using the OpenCV libraries in openframeworks) allowed the *skeletonisation* of the silhouette, with the identification of key articulation points at the elbow, wrists, tips of fingers and thumb.

Watson suggests future development could use the *depth information* to allow the 3D reorientation of the character and the exploration of other poses, moving beyond the 2D surfaces of conventional shadow screens. The setup of the installation afforded a more *open* proxemics:

> "Children can also step in to the environment and interact with the puppets directly, petting them or creating food for them to eat. This dual interactive setup allows children to perform alongside the puppets, blurring the line between the *audience* and the puppeteers and creating an endlessly playful dialogue between the children in the space and the children puppeteering the creatures." (Watson and Gobeille, 2011a)

The project utilised blended procedural animation, flocking, particles, plant growth with movement controlled and triggered by the movements of tracked participants.

Like Worthington and Levin (Figure 9 andFigure 10 sound was also procedurally generated in response to the hand movements of the two main bird protagonists.

In the prototype demo documentation, Watson and Gobeille (2011b) refer to a rapid design process familiar to puppeteers working on *scratch*, improvised and instant performances (see Improbable Theatre, Matthew Robins, Bunk Puppets). Quick prototyping is a testament to the nature of the OpenFrameworks toolset, the original work was built in a day. Watson and Gobeille have open-sourced the arm recognition code.

2.4.8. MIWA MATREYEK *DREAMING OF LUCID LIVING*

Figure 13: Miwa Matreyek. Scenes from 'Dreaming of Lucid Living' (2009)

Miwa Matreyek, an experimental animator and multimedia artist, came to widespread recognition at a 2010 TED talk in Oxford. Her piece “Dreaming of Lucid Living” (2007) is a carefully choreographed interaction between projection mapped animated media and the performers shadowgraph. At various times we see in silhouette the full body, head and hands, with a variety of physical props and virtual adornments. With respect to the style and flow of the piece: the separate vignettes and segments are stylistic of much shadow theatre. The colour-scape mimics the greyscale palette of shadow theatre, with lavish splashes and crescendos of colour as the piece progress (see Figure 13).

At times, the performer plays with space both in front of and behind the screen. The silhouette as a semi-illuminated relief integrates with animated actions becoming part of the montage and, when behind the screen, the darkness is augmented with projections mapped within the boundaries of the silhouette. The piece is a digital extension of a shadowgraph performance with its careful synchronisation of recorded sound, image and movement. It can be viewed in direct contrast to the chaotic real-time responsive installations of *Messa Di Voce* or *Puppet Parade*.

The work is a choreographic scenography, where the human role plays bit-part to the flow and mapping of animated images. Though not totally effaced, the performer eventually breaks free of the surface, transgresses the image boundaries and builds a projection-mapped cityscape.

Like nineteenth century shadowography:

> "The virtuoso shadowgraph performance did not efface the performer positioned behind the screen in order to intensify the projected fictions but rather emphasised the performative nature of the screen images in order to continually remind the spectator of the shadowgraphist's very presence." (Solomon, 2000, p.13)

2.4.9. SUE-C: DIGITAL-ANALOGUES AND PERFORMANCE ANIMATION

Sue-C (2013), a visual artist and film-maker, performs a mode of traditional shadow-object and projection play, after Schönewolf and others, but with a contemporary digital set-up. I include a brief reference to her process as her apparatus reconfigures the traditional shadow screen and over-head-projector into an original form. Using a laptop with a Max/MSP patch doing video image processing, a highly controlled lighting set up, including a Gepe light box, Sue-C videos and manipulates physical objects (slides, translucent materials) and creates real-time images and textures in response to live music performance, see Figure 14, below.

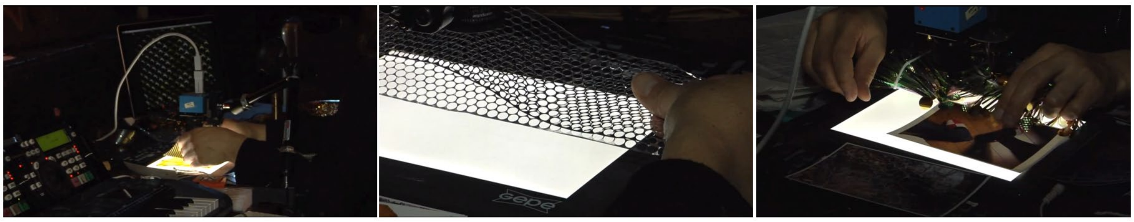

Figure 14: Sue-C's analogue / digital shadow object crossover techniques (2012)

2.5 THEMES AND ISSUES

A theme of the Practice Review and my conclusion is to emphasise the act of performance: What role has performance in transforming a visualisation or a simulation into a pure puppet?

We need to advocate pulling impressive demos out of the lab and into performance. This may be by pursuing the technologists with requests to use their tools and collaborate or making tools that emulate the same kind of outcome.

In the ShadowEngine project, I explore the practicalities of digitising heritage shadow puppets for use in live performance. The projects go beyond simple interactive 3D models and present an approach where game technologies, physical simulations and tactile interactive strategies (multi-touch surfaces) permit the user/performer to animate—live in real-time—articulated screen based figures. Puppets and performing objects *live* in expressive contexts. The ShadowEngine software and setup allows kinetic objects to be selected, operated, and placed in a scenographic context. Puppets are operated to form the basis of, for example, narrative play. Kinetic and experiential qualities are a major component in the *recontextualisation* of such performing objects.

Digitisation is central to contemporary processes of archival storage and information retrieval. For books, images and video, digital optical recognition and scanning is commonplace, the act of curating geometry and surface qualities and textures of 3D objects through digitisation is emerging (e.g. the European 3D-Coform consortium (2011) digitised a Mr Punch glove puppet from the V&A's Theatre Collection in the UK). The use of portable 3D scanners to digitise heritage artefacts offers interesting models for the archiving of fragile kinetic material.

2.5.1. QUALITIES OF ANIMATION: SIMULATION, CHAOS AND ACCIDENT

There is a divide between digital puppetry graphic environments that use physics simulation to act upon the performance objects and those that do not (and one - the Fluid Interface Group at MIT who blend both). It will be a point of future evaluation of the nuances of expression that both facilitate.

A theme emerging from a number of projects is the combination of animation that is:

1. Driven by user—both performer and audience—interaction;
2. Driven by objects under physics simulation (e.g. gravity on joint chains or flocking algorithms);
3. Driven by pre-made and blended with simulated animation;
4. Automated using generative non-planned techniques (behavioural simulation);

Qualities of animation relate the *expressivity* of a moving object with its *liveliness*. By liveliness I refer to the analytical framework of motion perception in the work of Rudolf Arnheim. Chow (2012) usefully places Arnheim into the context of animation and Eastern traditions (and builds a connection with the major shadow puppetry cultures):

> "For Arnheim, what counts as liveliness is not whether there is really a mind or soul, but rather the level of complexity in the observed behaviour. He delineates different degrees of liveliness according to different levels of complexity, from simple movement to complex behaviour, as shown in the following list:
>
> 1. Something that moves is livelier than something that does not.
> 2. Movement involving internal change (i.e. change in shape) is at a higher level of complexity than rigid object displacement.
> 3. The thing moving by its own force (i.e. self-initiated movement) is higher in degree of liveliness than that physically moved by others.
> 4. Those self-movements initiated by internal impulses are livelier than those driven by external forces." (Chow, 2012 , p.178)

For Chow, it is movement emerging from the *automatic* that carries expressive potential (or liveliness). Control should beget the opportunity for accidental movement.

> "Naturally, as a manipulated object, the puppet can only begin to approach real being by detaching itself from any external control. Its first task is therefore to capture the sense of naturalness implied by freedom of movement. For Kleist movement is natural when it is automatic; habitual but not willed. The natural is

> a mechanical response, and the puppet is perfectible because it has a memory but no will. In this line of thinking the mechanical and the natural are matching towards some sort of cybernetic union where mechanical perfection means not only the absolute reproduction of the real, but freedom from accident." (Paska, 2012, p.139)

It is through certain control methodologies of digital puppetry such a *union, as Paska describes,* can be formed: between technical control and accidental free movement. My exposition is: expressive potential is unlocked when a combination of direct control, physical simulation and automated techniques are blended. My practical experiments aim to test this.

2.5.2. PERFORMER AND PUPPET PROXIMITY: TOUCH AND ERGONOMICS

In *The Puppet Tree* (Kaplin, 1999), see Figure 15, Stephen Kaplin presents one of the first theoretical puppet models to include digital puppets and avatars in a continuum with tangible puppets and actors. Kaplin uses the distance between operator and performer as a means of drawing distinctions between puppet forms (*y-axis*). On a central *Performer/Object trunk*, he connects a chain of *puppets* from *the actor-in-role* through to the virtual performer. I have added labels to emphasise the close relationship of [1] virtual figures to [2] shadow figures. The *x-axis* captures the extent of collaboration involved in producing the total image of the puppet in performance and describes particular manipulation techniques: a many-to-one ratio would describe a Bunraku performance where multiple puppeteers control a single figure. A one-to-many ratio describes circumstances where an operator may control multiple figures: for example the dance puppeteer Christopher Page's *Jackson Five* act[8]. In virtual space, one

[8] Christopher Page, dance-puppeteer: http://www.johnstuartproductions.com/Christopher%20Page.htm [Accessed 4th May 2018]

performer gesture or action can be mapped to control multiple screen figures with each move modulated through code.

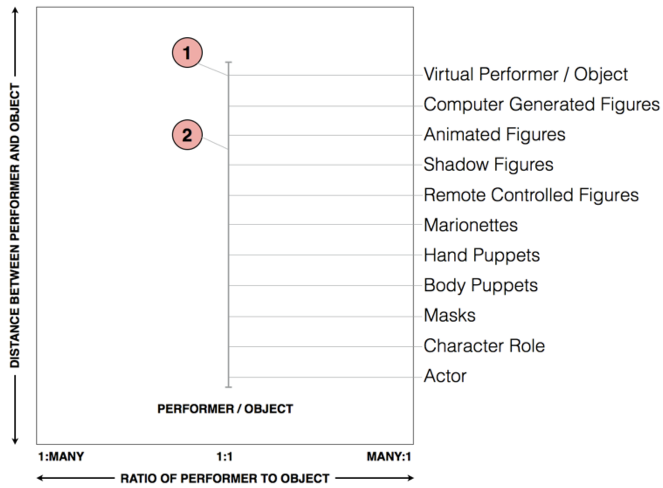

Figure 15: Visual simplification of Kaplin's Puppet Tree (1999) by the author.

In the context of the ShadowEngine projects, distance of the operator to puppet is a conceptual problem given that tele-remote control and computer mediation potentially simultaneously collapses and expands distance in an arbitrary way. Hence 'control' is determined by conscious decisions about configuration and each system is potentially a new system to learn to control and master.

2.5.3. DEAD PUPPETS

The interest in dead media as obsolete communication media and devices in Sterling's sense (see Section 1.6.1, above) extends to a broader interest in the deadness of puppets-as-objects and objects-as-puppets and their enlivenment through manipulation.

> "[W]e could say that the essence of puppet, mask, and object performance is the animation of the dead world by living humans"(Bell, 2014, pg.43)

In the exhibition "Dead Puppets"[9], Nenagh Watson presented a serious of installations that dragged puppet figures and objects from archives and collections back into liveliness. Some figures in the exhibition were famous television puppets. 'Muffin the Mule', loaned from the Hogarth Collection, had an insurance excess of £10,000 and required individual security. To inspect the shadow figure gallery in the exhibition, Watson gave visitors torches to shine upon figures hanging in a darkened room. The objects cast large, moving shadows, releasing the object from its display state into an animated projection containing multiple, overlapping forms in a playful montage.

Watson has a broader interest in the automatic animation of everyday objects via elemental forces: umbrellas, clothing and plastic bags in the wind. She is interested in the after-life of broken or discarded objects.

From the research proposal for her research fellowship at the Royal Central School of Speech and Drama "Conversation with the Dead Object", Watson (2011) asks:

> "How do 'lifeless' figures hanging within a museum display honour memory of their past 'liveness'? And how does the implication of the puppet's death or 'deadness' bear upon our sense of its (previous) life?" (Watson, 2011)

She continues:

> "Should puppets be re-used after their creators are gone? How do lifeless, dead figures hanging static within the context of a museum display honour memory differently than reconstructed performance?"

These ethical considerations feel more deeply personalised than when dealing with found objects, from a museum, without an apparent past. Watson also worked on a project enlivening

[9] DEADpuppet Exhibition. 2013, Z-Arts, Manchester, UK.

a set of Punch and Judy puppets she inherited (or bought through auction) belonging to a Punch professor (Joe Beeby) (Watson, 2018).

Dennis Silk, poet and puppeteer, has a similar focus on the dead puppet object. In his 'Thing Theatre' and his essay 'When We Dead Awaken', he engages us with his open sense of what can be a puppet:

"Thing theatre? What does that mean? It means a theatre where things are granted a higher dramatic status than in the theatre of the personal actor." (Silk, 1996, pg. 228`)

Both Silk and Watson find appeal in animism where movement brings a liveliness to found objects. In the ShadowEngine, I seek technological means to restore to found objects the ability to move, to be controlled and find expression. The materiality has shifted from atoms to the bits of digital objects: of code and data representations.

> "Any sense of life or independent action in them (objects) is a matter of imaginative suggestion, and their 'death' is expressed as a transition from one form to materiality to another... " (Williams, 2014, pg. 20-21)`

2.5.4. EXTINCT AND LIVING TRADITIONS: ETHICAL CONSIDERATIONS

The interest in dead media and Sterling's inclusion of shadow figures in his master list of dead media does not mean we are dealing only with extinct traditions or historical artefacts.

There is an important ethical and cultural point: some of the shadow puppetry traditions are living forms. Some are listed by UNESCO as belonging to the intangible cultural heritage (ICH) of humanity.

Digital approaches seek to preserve intangible cultural heritage while simultaneously transforming such practices, through technological means, in quite radical ways. In line with the broad safeguarding efforts of UNESCO, my ethical effort is to enact the documentation, preservation, promotion, enhancement, transmission and revitalisation of traditional shadow theatre practices through digital and creative means. My aim is intended to support existing communities of practice and not propose an alternative form by appropriating and repackaging them via new technologies.

2.6 ONWORD

> "Having no interior life…the puppet is, strictly speaking, incapable of expression. Having nothing to express, it can express nothing. The mask of an actor or dancer, conceals the density of humanity; the puppet, nothing but emptiness. Nothing. What is the Nothing that hides behind the mask of the puppet? What is the puppet stripped bare? The fascination of the puppet, its secret power of seduction, lies in what it hides, not what it expresses. Narrative, mimesis, representation: all *orthodox* aspects of puppet theatre in the West. Little human simulacra illustrating human quirks through the imitation of human poses and gestures. Mimicry and parody as the twin peaks of the puppeteer's art." (Paska, 2012, p.136–7)

If the trappings of the (digital) puppet tend to hide and mask the *expressions* of the operator, where is the space to find the *expressive* potential: through what kind of manipulation and techniques? I propose through the sensitive mapping of *touch* and digital (finger), hand and body movements.

The *nothing* of the physical puppet Paska exposes, above, maps nicely onto the intangible virtuality of the digital puppet: where the digital figure is a simulacrum set up to imitate the gestures and movement of physical objects.

Using innovative human interface devices, such as the Kinect, the Leap Motion and multi-touch surfaces, and harnessing their expressive potential, are acts of pure puppetry;

As long as it remains in the mode of performance, is tested by means of performance, and if begat through performance. Make the move from the lab, from the demo, to the performance space, where as Paska has it, all reckoning begins.

> "The puppet-as-object in live performance still represents the *zero degree* of puppetry (the point from which all reckoning begins)." (Paska, 2012, p.139)

In conclusion, the collection of practice considered in this section unites to tell a story of the continuation of shadow theatre aesthetics in the post-digital age. My motivation is stimulated by an interest in the *digital analogue* (discussed in Section 1.4, above) involving the physical roots of virtual images, and the interplay of darkness and the luminescent in an immaterial domain.

> "The power of such images—the silhouette, and the black-and-white portrait photograph—arises from their origin in the light that once played on their subjects and formed their image. They are emanations, captured and stilled. Is that a figure of speech? They are copies of the originals, and, in that sense, their character ceases to be metaphorical. It is here, on this edge where the figurative touches the actual and the image becomes reality, that shadow eerily communicates individual presence; this effect grows when a shadow becomes a shade, and that shade a reflection; then the projected image of a person brushes the condition of spirit." (Warner, 2006)

3. NEW STUDIES

The goal of digital puppetry is not to replace the traditional puppet, but to identify ancient puppet qualities and bring them to bear in order to extend and enhance our sense of the digital puppet in performance. The goal is to draw on traditional insights and skills to unlock the liveliness of our digital puppets, devising intriguing mechanisms authorised by powerful new technologies, to let animation happen in as fluid and expressive a way as possible.

3.1 THE SHADOWENGINE

To deepen the exploration of digital shadow puppetry and evaluate the expressive potential of multi-touch interfaces as performance tools for the puppeteer, I created a series of projects named the *ShadowEngine*. The ShadowEngine presents a developing set of experiments in software design that examine mechanisms for touch driven puppeteering, each addressing the following objectives:

1. To devise different methods of character control and rigging for expressive real-time animation;
2. To explore interactive dynamics that is: blend physics simulation and user interaction to create emergent character movement and expressive figure behaviours;
3. To draw on the aesthetics of the silhouette and techniques of shadow theatre.

The work has taken a number of forms, utilising figures from various world puppetry traditions seeking cross-over insights between traditional material practice and digital methods.

I set out to address the follow areas of enquiry:

1. How do the domains of digital puppetry remediate traditional shadow puppetry?
2. How can touch and gestural interaction facilitate expressive puppeteering and collaboration in digital shadow play?
3. What are the most effective methods to create and evaluate digital shadow production and play?

In the current chapter, I critically reflect on the projects, in rough chronological order, and describe the stages of work, reporting on the design and execution of each significant experiment. My report on the process of design and coding includes phenomenological detail around constructing and using virtual puppets in digital environments (the digital craft of assembly, configuration and setting performance control). It is in and through such detail that analogies between the focus of the traditional 'analogue' puppeteer and the digital puppeteer are made manifest.

I present a critical-reflective commentary dissecting the achievements, discoveries and difficulties encountered.

The video documentation in *Appendix A* is central to this chapter. Important insights were generated by testing the touch manipulation, trying reconfigurations and playing with the figures and creating live animation. I created a Video Comparison Tool (*A-2 Video Comparison Tool* - online and archived in the accompanying media) to help structure and code the observations in *3.9 Iteration 5: Movement and Control.* Where possible, I link to specifc parts of the video documentation. Some of the video captures have been designed to visualise—with a split screen, touch markers in the scene, visible on screen puppet controllers— the interplay between figure animation and the touches. Clear themes emerged through the observations of quirks, usability issues, effective/ineffective physics, gestures and manipulation techniques.

The ShadowEngine project, as presented, may appear to have coherent, chronological development. However, to characterise the intricacies of development like that would be misleading, for a variety of reasons. Digital artefacts have a propensity to be versioned and re-versioned: software bugs are tracked and resolved and features are added—especially when I learnt a coding technique to solve a problem and could retrospectively apply it.

My programming abilities were limited in the earlier phases of the work. Revisiting these projects created a near continuous potential for discovery and iteration.

> "the position of the digital artwork [is] fundamentally entangled with circuits of replication, recombination, dissemination, and along with them, endless potentials for productive mutation" (Anderson, 2006, p.4)

3.2 OVERVIEW

Section 3.3 Creative digital processes and methods presents a diagram of the digital methods used to create animatable digital characters from tangible images and objects. It synthesises all of the approaches used in a flow-chart and presents the main terminology common in each iteration and some technical details.

In *Section 3.4 Iteration 1: Foundations - Exploring physics based animation,* I present early formative explorations and experiments that help frame the purpose, rationale and trajectory for the ShadowEngine. This section considers: early physics engine play, exploration of softbody and rigidbodies, the position of automata in puppetry, and audience empathy with simple animated forms.

Section 3.5: Iteration 2: Mono-touch documents the design and execution of the first prototype that demonstrates issues ranging from control, presentation (*object properties and the nature of shadows*), *emulation/simulation, perspective* and *dynamism*.

I establish the context for expanding the interaction/control principles from mono to multi-touch.

Section 3.5 also identifies the cultural issues around the digital remediation of world shadow traditions, especially the radical decontextualisation and hybridisation of form that occurs when fusing digital culture with older traditional practices.

Section 3.6 Iteration 3: Multi-touch, collaborative control, visual design and cinematics presents a further evolution of the aesthetic and technical capabilities of the ShadowEngine system: including multi-touch, remote control of figures using Open Sound Control (OSC) protocols, optimisations in character rigging time, visual design and cinematic enhancements. Significantly, character setup time was cut from 2-3 hours to 20 minutes. Ostensibly relatively simple matters addressed here prompt a set of rich emerging questions, insights and excitement.

Section 3.7 Iteration 4: Digital Restoration and Puppet media archaeology explains the rationale and digital design processes that underpin the digital restoration of physical shadow puppets from the Turkish Karagöz tradition digitised from the French collection of the Institut International de la Marionnette (IIM, Charleville-Mézières), and a near-forgotten 19th century British shadow[1] play “Billy Waters, the London Fiddler” (c1850). With ‘Billy Waters’, the digital restoration process enacts a digital media archaeological method. The puppet figures were digitally restored not from objects but from a PDF scan of theatre ephemera sold as a playtext containing a toy theatre sheet of wood-cut illustrations to be cut-out and assembled and used as silhouettes.

Section 3.8 Interlude: Crafting The Digital Hand was a necessary digression exploring Lotte Reiniger’s construction of a hand—actually a miniature component of another figure—pictured in her seminal book *Shadow Theatres and Shadow Films (1970).* Highly curious about how it could move, I just had to attempt a digital reconstruction.

[1] Not forgotten by Prof. Matthew Cohen who re-discovered ‘Billy Waters’ and identified it as a subject for digital reconstruction.

Section 3.9 Iteration 5: Movement and Control compares in more detail the variation of movement and control approaches. As the ShadowEngine project progressed, the visual elements came together and touch puppeteering principles established. This iteration systematically documents a selection of physics and non-physics based rigging approaches.

1. Puppet figures suspended in a spring network of controllers,
2. The direct manipulation of figures, and
3. A non-physics based kinematic algorithm – using Forward and Backward Reaching Inverse Kinematics (FABRIK) chains.

To conclude the *New Studies*, I re-address the objectives, and present a set of themes and emerging questions for further discussion in *Chapter 4, the Conclusions.*

3.3 CREATIVE DIGITAL PROCESSES AND METHODS

The iterations of new studies established a digital workflow for producing animatable digital shadow figures. Figure 16 below, presents the workflow as a flow chart that captures the variety of methods, techniques and terminology used as the project progressed and as softwares changed. The account describes the creative digital processes synthesised across all iterations.

Several videos in the documentation show screencasts of these creative processes sped up. There are important analytical moments in the workflow where puppeteer knowledge is applied: conceptually deconstructing how a figure is articulated and assembled, then actively deconstructing/reconstructing through digital manipulations (for examples see Video 27, Video 34, Video 39)

3.3.1. ACQUISITION AND IMAGE PROCESSING

1. Figure image acquisition

Image acquisition involves the digital scanning or photographing of figures. I acquired material from physical collections of objects in Museums, books, theatre ephemera and performance documentation. My studies all focus on 2D images. I identified other projects that implement this workflow with 3D imaging of puppets, notably the Co-Form project at the V&A (3D Co-Form Project, 2011) who digitised Mr Punch for real-time animation in Unity 3D. If the figures are translucent and colourful, capturing the surface detail is important. If the figures are opaque, surface detail is less important than recording the parts and jointing positions. At this stage, for an open creative process not based on existing puppets, you can trace, draw, scan or assemble imaginary figures.

2. Analysis for Movement

A close analysis is made of the shadow figures' form and structure in order to 'decompose' the figure into its articulated parts and the points of control. How the figure is proportioned and weighted, and from where it is held, its rods and pivots, affect its animatable character: how it swings, its balance, its position of repose or rest. Puppet makers care about how their figures find grace in movement and stillness. Sometimes this is clear, other times it is subtle. If the physical objects have not been handled, the analysis can be speculative and deductive. Later, limbs can be made jointed, constrained within limits, flexible or fixed in the games engine (Unity 3D in my case). This part of the process represents a digitally assisted media archaeology: recovering the animatable qualities of shadow figures.

3, 4a, and 4b. Digital Image Manipulation

These steps involve digital image manipulation and digital painting to extract the figure from its background, and prepare an 'atlas' of the separate parts of the figure, with careful annotation of 'pivot' points and joints. If the source image is distorted, image editing tools like Photoshop or the Gimp, can help de-skew and fix perspective distortions. This process rescued an obscure source of data for ‘Billy Waters’ (Video 40 03:12). Digital painting restoration technques can be used to paint and clone missing elements, remove dirt, etc. Painting the cut-out detailing is a significant act of study of cutting patterns and technique, especially in detailed, ornate figures with sophisticated repeating motifs (Video 39, Video 34 at 02:44). The two panels, 4a and 4b represent a software tool that became available to automate this part of the process.


1
Figure Image Acquisition
Scanning
Photography
2
Analysis for Movement
Decomposition
Figure parts and joints
Range of movement
Potential control rigs
3
Image Manipulation
Deskew
Photoshop
Perspective corrections
Foreground extraction
Create mask / select figure
Separate parts
Mark pivot and rod points
Paint
Occluded elements
Paint and clone
Missing elements
Touch-up and lighten
Overlaid colours
Erase
Pattern cuts and silhouette detail
4a
Atlas production
Export
Transparent PNG
Photoshop
Each part or as atlas
Optimise packing
Destination: mobile
Power of two textures?
4b
Atlas production and auto-pivot setting
TexturePacker
Create workflow
Set pivot points
Desktop / mobile
Export
XML / JSON for Unity
5a
3D Modelling and Texturing
Import assets
Modo / Maya
Trace geometry
Extrude
Optimise polycount
Create UVs
Texture
Position centres / pivots
Export
FBX
Set world scale
5b
Image based 3D modelling
UCLA Gamelab Mesh Creater
Unity 3D Asset
<- Automates that
5c
2D Assets and Spritesheets
Uni2D
Unity native sprites
6
Layout, configuration and rigging
Unity 3D
Import geometry or sprites
Check scale / import scaling
world to game units
layout
Correct pivots / object centres
Layout - align jointed parts
3D - Offset-parts on Z axis
2D - Set sorting order
Visual / texturing adjustment
set alpha / shader types
physics
Create rigid bodies per part (3D or 2D)
Create colliders per part as required
Set physics behaviours - per part
mass
gravity
linear drag
angular drag
axis constraints
Rigging and Interactive control
joints
Apply and configure joints (fixed, springs or hinges)
rigging
Consider hierarchy of parts
identify root object
Parent logically
Flat heirarchy
Interactive control
Create hierarchy of control objects
Parent directly
Connect to parts with spring joints
test and iterate
6b
Rigging and Interactive control
Alternative Approaches
Collision objects
Direct control
Spring networks
Inverse kinematics
Forward and backward reaching IK
7
Scripting
Interactive control
Script Interaction mode on key control objects
Kinematic mapping
UniOSC
Remote control with Open Sound Control (OSC)
configure addresses
mouse
scroll wheel
EasyGesture
touch
gestures
pinch
twist
tap
double-tap
Open NITE
embodied
gaze
Special Effects
Scaling
Rotation
Colour
colour
greyscale
monochrome
Selection management
hanging
Custom animation
eye blinks
transforms
holding objects
Connect to UI
Expose key functionality to UI

Figure 16: Creative methods for digital shadow figure production

3.3.2. 3D MODELLING AND TEXTURING AND SPRITES

5a, 5b and 5c. 3D Models and 2D/3D Sprite Generation

In the early iterations an optimised 3D mesh was prepared, constructing geometry upon which to texture map the separate parts of the figure. Attention is paid to centre and pivot points and the hierarchies of exported 3D objects (See Video 4 at 01:34, 02:32, 08:00). This was very time consuming. However, the tools are continuously evolving: the UCLA game lab produced a tool[2] to create simple meshes from image textures based on transparency. Later, other third party tools added sprite based 2D workflows, e.g. Uni2D[3], then Unity 4.3 added their own 2D sprite based work-flow, incorporating Box2D physics (September 2013). It took three years for this feature to settle and work as expected. The tool sped production up, but also created physics setup problems around scaling, rotation and weight (see Video 38: the glitches resemble trick marionettes where the body parts separate in an entertaining way).

3.3.3. RIGGING

6. Layout, configuration and rigging

We export the 3D geometry or sprites into a games engine for layout, visual adjustment, scaling, jointing, fixing object centres, applying physics behaviours and settings, creating collision objects, parenting objects, simulation testing. I use Unity 3D. The process will be comparable with other digital content creation software and games middle-ware.

[2] UCLA Mesh Creator http://games.ucla.edu/resource/unity-mesh-creator-2/

[3] Uni2D http://www.uni2d-plugin.com

6a and 6b. Rigging for interactive control

The first prototypes in iteration 2 and 3 (see pages 122 and 132) use a direct manipulation model of touch control. I evolved a control rig of touch-points connected to a figure in what I call a 'Spring Network'. The multiple figure controllers can be parented in different hierarchies and collected in sets—where one controller moves others. There are clear demonstrations of such control hierarchies and controller sets in the following videos (Video 16, Video 17 at 00:29, Video 20. Video 27 explores the power of controller sets. It can simplify control and customise the elements that require an impulse to move)

6b lists the different rigging approaches created and compared in Section 3.9 Iteration 5: Movement and Control: Direct control, spring networks, forwards and backward reaching inverse kinematics (FABRIK).

3.3.4. CODING / SCRIPTING

Once created a figure can be assigned behaviours through code. As the project progressed, I improved at abstracting code into smaller units of functionality. In the later iterations quite complex functionality has been encapsulated into a 'tool-box' of scripts. See Appendix C – Code Repositories. All the projects and code can be read online or in the submitted archives.

Scripted behaviours for figures include:

Kinematic mapping and Interactive control for movement: Controller items or figure parts can be mapped to data from mouse dragging, mouse-scroll wheel and multi-touch controllers. Additionally, I tested data mapping for Kinect (OpenNI[4]) sensed body parts, Leap Motion[5] hands and fingers and Eye Tribe[6] eye-tracking;

[4] OpenNI http://openni.ru/files/nite/index.html

Gestures: The Controllers can be mapped to particular fingers/touches. Through a third party library, touch gesture recognition can be added to controllers or figure parts: pinch to scale, twist to rotate, tap, double tap.

Remote control (send and receive): Controllers can be set to send and/or receive Open Sound Control (OSC) signals to allow remote control (position, rotation, colour effects) through a partner app (see *Section 3.9 Iteration 5*).

Special Effects: Objects may need to scale, rotate, change colour (we have monochrome, greyscale and colour modes) or have custom animation.

Attachable/Detachable objects: A script can help a character figure hold and drop objects (see Video 42 at 08:50 and Video 45 at 01:45)

UI, Keyboard Bindings and Persistent settings: There is a UI and persistent stored state providing the architecture for recording preferences and other puppet figure data including: controller object position, object status (enabled / disabled), and grouping. I created *helper scripts* that implement object control from keyboard bindings and UI controls.

Editor Utility Scripts: I created tools that allow character selection, animation actions, and display all spring, hinge and physics settings for objects: exposing configuration to speed up the constant tweaks required when rigging for interactive control.

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[5] Leap Motion http://openni.ru/files/nite/index.html

[6] Eye Tribe http://theeyetribe.com/. Sadly the hardware has been deprecated. TheTobiiEyetrackers are an alternative to explore.

3.4 ITERATION 1: FOUNDATIONS - EXPLORING PHYSICS BASED ANIMATION

I wish to explore interactive dynamics in real time physics based animation. In plain English, I seek a solution allowing puppeteers to touch and control screen based puppet figures while the figures are simultaneously under the control of physics simulations.

There were two formative happenings in the early research stages that generated effects and questions pertinent to the wider study:

1. Puppeteering the Box2D[7] Theo Jansen's Walker demo;
2. Creating a set of 'Springies' (named after a Chipmonk2D[8] demo).

I create parallels between Kleist's interests in the centrality of gravity and pendulum and the experience of playing with a variety of physics demos in the pursuit of expressive movement and control.

Observing simulations of natural motion, even physically inaccurate ones, has an appeal and is full of expressive potential for the puppeteer. Why so? I believe we see the emergent qualities of expressive animation: anticipation, vibration and vibrancy, secondary and tertiary motions, timing and easing function (slow-in-slow out) and arcs, as described by Lassetar (1987) after the Disney animators Thomas and Johnston (1995).

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[7] **Box2D** A 2D Physics Engine for Games: http://box2d.org

[8] **Chipmunk2D** Game Dynamics <https://chipmunk-physics.net>. Is a physics library that can be used on a variety of platforms, including devices with touch screens that support multiple points of touch.

3.4.1. THE THEO JANSEN'S WALKER DEMO IN BOX2D

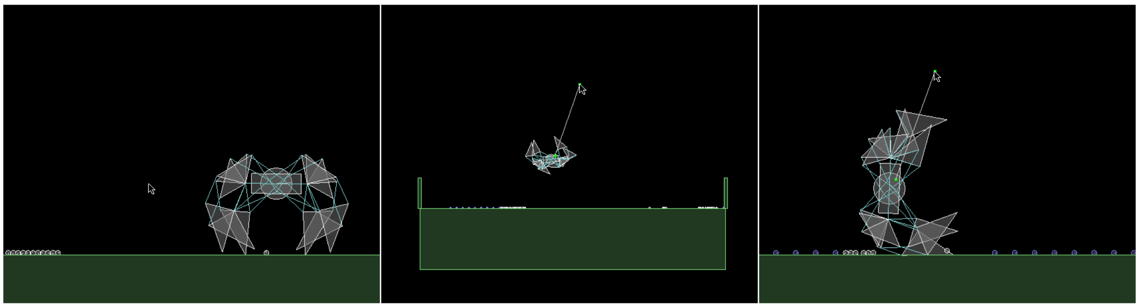

Figure 17: Interactive dynamics in Box2D: Theo Jansen's 'Walker' - liveliness and empathy

Video 2: https://vimeo.com/224844059 (00:19)

The Box2D demo is a 2D simulation inspired by the Dutch artist Theo Jansen's 'Strandbeest', a large mechanical walking automaton.[9] The 2D assemblage is built of a few connected squares, triangles and circles pivoted and jointed, drawn as a wireframe with simple shading. The object has a circular 'motor' driving the connected leg mechanisms in patterned and constrained movement effecting a walk. Simple keyboard interaction applies braking and acceleration forces along the ground plane. Mouse interaction can 'pick-up' the object from any joint, swinging the crab-like creature in a springy dangling way. While picked up, the motor keeps animating the object, creating a liveliness and a response from almost all audiences I've demoed this proto-puppeteering to: producing an audible empathy towards the dangling 'mistreated' figure. A single line (vector) is drawn indicating the strength and direction of the mouse movement and point of contact with the figure. The jointed body moves and resists in response. The ground plane applies friction to the hapless, tripping body. Any attempt to right the moving figure leads to a dance of resistance and most often technical failure. The tendency to anthropomorphise such technologically animated figures, persuades me of the potential to design expressive digital

9 See Theo Jansen's Strandbeest <http://www.strandbeest.com>

forms. The assumed agency due to the self-motoring animation is a sign of animus, readable by an audience.

This work provides the digital puppeteer with the following insights:

1. Rather than a ‘single string’, multiple points of contact may increase controllability and stability when puppeteering the object;
2. The physics responses—the bounce, spring and damping[10], the restitution[11] and added complexity of autonomous motion provided by the virtual motor—lend a complex set of behaviour and ‘expressivity’ to the 2D digital puppet;
3. Simple constructions when jointed or connected in chains can be expressive when simulated mass, gravity and impulse work with and against puppeteer interaction;
4. Audiences empathise with simple forms in motion; Intentionality is projected upon a digital construct that has volition leading to a sense of liveliness;
5. Simple mono-touch (or mouse point and click interactions) lead to the beginnings of a *dance of agency* between puppeteer user, digital object and the audience.

3.4.2. NETWORKS OF SPRINGS: DIRECTED AND UNDIRECTED MOVEMENT

The Chipmunk physics 'Springies’ demonstration illustrates a number of points of interest that a 2D physics simulation of mass and springs can provide a digital puppetry system. The demo comprises a network of objects resting in a simulated spring system. Some objects are simple, and others made of compound jointed objects (not pendulum as no end point is free swinging).

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10 Damping: the restraining of vibratory motion.

11 *The Coefficient of Restitution:* the retaining or loss of kinetic energy when objects in motion collide.

Fixed points (black dots) anchor and surround the system. A single mouse click and drag on an object moves the object and accumulates force the further it is pulled. Upon release, energy is distributed through the system of objects, fixed constraints and springs and the whole takes on a liveliness of apparent unpredictable motion. As damping applies and the springs come to rest there is an attractive quality to the flow of movement: vibrations diminish, the objects ebb and flow against each other in a gentle undulating rhythm; a network of connection is perceived as each object finds its state of rest. In this simulation, all objects come to a complete rest. Such is the configuration. It models the kind of fall-off of kinetic energy observable in natural movement. Physics simulations, like these springs for example, can be configured to have impossible attributes, where damping doesn't occur or momentum perpetually increases.

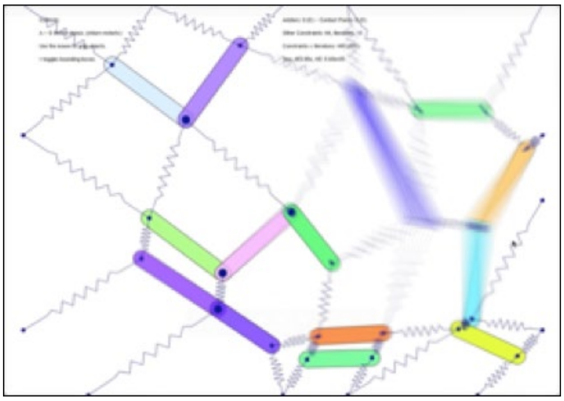

Figure 18: Chipmunk Physics 'Springies' Demo

Video 2 https://vimeo.com/224844059 (01:40)

In puppetry, a completely still object is often viewed as lacking life, having no sign of energy and no illusion of *breathing*. Leaving an object to 'die' is sometimes viewed as a transgressive act that draws attention to the mechanism and artifice of the performing object.

What expressive potential can be observed in the visual dynamics of the simulation? The physics simulations provide an 'organic' and vital feel to the animation. There is expressive potential in the pattern of movement decay of the digital object towards motionlessness.

A gentle interaction with the spring system imbues a dynamic that cascades (and then diminishes) throughout the structure. In studies of the perception of natural motion (Gibson, 1986) the spring has special status. Undulations and motion decay, and their related wave forms are analogue forms easily mimicked in the Newtonion physics simulations of game engines.

Some points to note: In this simulation none of the objects collide – rather they smoothly intersect each other. The game engine terminology for this is the *rigidbody objects* do not have *collisions* enabled or a *collider* shape defined.

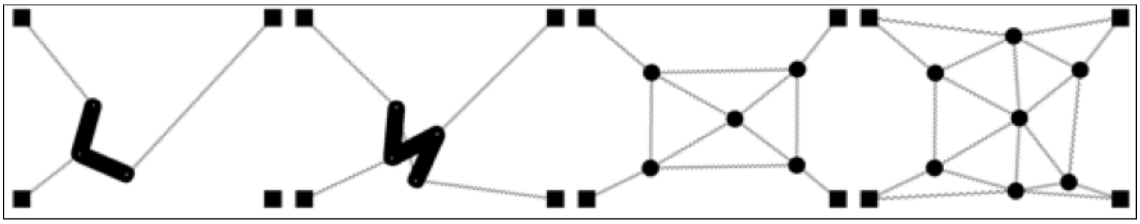

Figure 19: Springies (2010). 2D spring network with four variations (a, b, c, d)

Video 2: https://vimeo.com/224844059 (01:40)

Following this I made a set of variations in Unity 3D, see Figure 18, exploring the qualities of movement and movement potential across a range of objects – from single to multi-jointed objects to arrays of interconnects nodes. These studies aimed to:

1. Understand the properties of joints, springs, configurable joints in the 3D physics simulation in Unity, especially their limitations;
2. Observe the potential of control/non-control and directed/non-directed movement as important to expressive puppeteerly manipulation;
3. Describe the expressive dynamics of elasticity;

4. Explore the use of environmental properties collision, friction, other configurations in creating dynamic movement;

The configuration of multi-jointed objects involves a number of factors including: object mass, joint springiness and damping properties; axis of movement constraints; the strength and direction of gravity – which are easily reconfigurable in a games physics simulation. The direction of 'up' and gravity is important in physical shadow puppetry. For example: shadow puppeteers often rely on a 'friction board' as the base of a vertical screen as a means to anchor their figures and lever leg or body articulations. Also when pressed fully on a vertical screen, the screen itself is a source of friction to enable subtle joint movements. Shadow puppetry using overhead projectors or shadow puppets in animation, e.g. In Lotte Reiniger's shadow films, the performance surfaces are horizontal[12] – gravity and friction hold the objects in place. As such gravity assisted movement, swing for example, isn't as readily achieved – the construction of movement is very different.

In the virtual space of games, we can have a hybridisation of many physical orientations and spatial ordering. Gravity can be turned on or off (per object). Its direction and strength in an environment can be varied. The direction Up is a vector set by convention—usually in the +y or +z axis—depending on the conventions of the coordinate system. The mathematical definitions of perspective projection can be changed on the fly. Allowing for simulation of lens based / optical distortion, flattening and extenuation of perspective projections.

Some approaches to 2D games set up a scene where objects are laid 'flat' as if on a surface like a light box. Simulated gravity and friction holds the objects in place, but do not help animate the figures' joints.

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[12] Reiniger's silhouette film screens were also multi-planar, allowing parallax illusions of depth and a sense of layer-ordering as characters interact behind foreground objects and in front of background elements, each scrolling at different tempo.

This is a way to avoid physics glitches and failures – where integration calculations fail, sampling of velocity and position drift or accumulations of energy are added into the simulation ('noise accumulation'). Sometimes these glitches are desirable and lead to 'expressive' movement where physics figures dance or jitter autonomously. Other times such glitches lead to complete system failure, where component elements of an object explode as all joints fail.

In most game physics-engines, an object can be set to 'kinematic'—meaning its position, rotation and reactions to collisions in a scene are controlled by calculations driven by the physics simulation. On the contrary, an object that is not 'kinematic' sits outside the calculations of the physics simulation. Its position and rotation (transform) can be controlled by other methods of animation. It can still collide with other objects under the control of physics calculations but doesn't react itself.

In most games physics middleware, directly moving an object whose position and rotation are controlled through a physics simulation adds forces into the simulation that can lead to unpredictable behaviour.

Adjusting the 'mass' of a rigid-body under simulation lends a finesse over the control of pace and behaviour. As do 'damping' and other settings - variable on context and related values. The possibilities are enormous. Playing with such values during the running of a simulation is an important act of configuration, a requirement of creating expressive animations.

The elastic spring joints as visualised in these experiments resemble a marionette control method that uses taut strings in puppetry. In the simulations, such elasticity is configurable and can be tamed.

Strings are sometimes used to control shadow puppets, hung from above (like a marionette) or as a flexible joint between control rods and joints with an almost unlimited degree of freedom. In the latter example, the string is a kind of proxy object between the stiffness of a control rod and the stiffness of the jointed piece.

Following the demos, I identified a number of propositions to explore further:

1. Direct manipulation vs Indirect Manipulation: a mouse or touch gesture can *directly* drag an object along a trajectory, with a particular momentum, like directly holding and manipulating the arms of a doll. Should the dragged object be connected to other object or objects, with taut spring joints for example, the connected object is *indirectly* moved, and indirectly interacts with other connected objects in turn. Like a bar in a marionette controller: the bar connects to a string that connects, for example, to a knee that is connected to both a thigh and a foot. The bar *indirectly* manipulates the elements in its hierarchy or network. Its sphere of influence decays based on the properties of the joints in the network, including stiffness, friction, mass, angular constraints, etc.
2. In the demos, the spring network is connected within several fixed 'anchor objects' that do not move. What if they become the puppet controllers - not controlled by the physics system, but moved by user interaction? Each anchor could be 'parented' to another creating a system of control nodes – like a marionette controller with a detachable sub-rig for arm or leg control – moveable independent of the main controller. The system within the anchors animates freely or with restrictions according to the configuration of each singular joint;
3. Degrees of Freedom (DOF): Each joint is a detailed configurable entity (though defined joint types are available in most game physics engines). Therefore the systems of connection between multi-jointed objects and the properties of those joints play a great part in designing the expressive potential of a figure. The state of independent variables of joints in a multi-joint figure define the 'degrees of freedom' of that figure.

3.4.3. PLAY WITH SOFT-BODIES

In parallel, I created a set of experiments that tested methods of puppet control other than directly dragging chains of jointed rigid-bodies. and the movement potential of soft-bodies (see Figure 19, below).

Soft-body dynamics, in combination with user interaction and rigid body objects as colliders, provide a rich playground for the digital shadow puppeteer, analogous to material and textural play. Video 2 demonstrates the use of objects to prod, pull and push surfaces, creating an interesting morphing silhouette and set of kinetic transformations.

Soft body dynamics are simulations that help create emergent motion on 3D objects: jelly-like blobs, undulations, vibration, deformation, flex, deflation, inflations, and cloth-like behaviour. Cloth simulation is available in the Nvidia "PhysX" game physics solution, integrated in Unity. The following experiments were created to explore the richness of emerging movement.

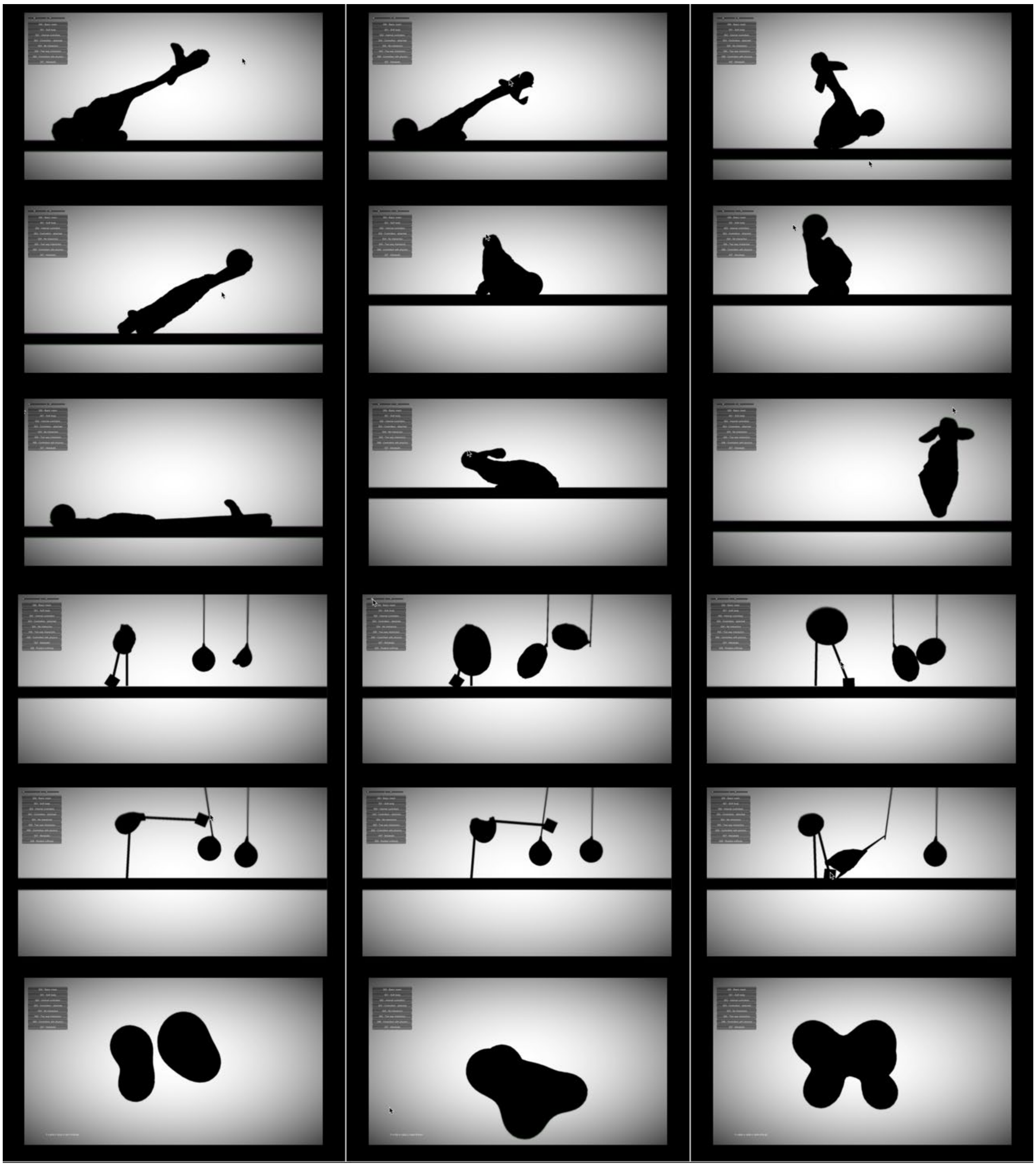


Figure 20: Foundations: Play with interactive soft-body dynamics (Unity, 2011)

Video 1: https://vimeo.com/218777295

I set up a parameter to control the 'internal pressure' of a soft-body. This led to a most interesting expressive effect, central in analogue puppetry: the illusion of breath. It also centred and de-centred the sense of where the impulse to move was coming from— puppeteer or object.

These experiments are a good example of a 'digital analogue'.

Play with light and shadow in the analogue, or tangible domain expands beyond traditional figures and scenography into non-figurative experiments and improvisational play with material simulation.

The material properties of traditional shadow figures are varied: leather with ornate cut-outs, fabric, twine, bone, paper, card and plastic - a variety of old and modern materials. They possess degrees of opacity, from translucent to opaque, where the projected silhouettes can be subtly colourised - some can be as vibrant as stained glass windows. In 'modern' shadow play, as documented, for example by Schönewolf (1969), Binyon (1966), Currell (1999) and Rausch (2005) depict projection experiments using wire, rubbish, fabrics, string, fluff, expanded metal, smoke, sand, fluids, oils, household objects and more. The qualities of the projected shadow of such material appear expressive textural and abstract, augment human shadowgraphs, like in Worthington (2012), or be fashioned into anthropomorphic figures.

3.4.4. SUMMARY – EXPRESSIVE DYNAMICS WITH SPRING NETWORKS

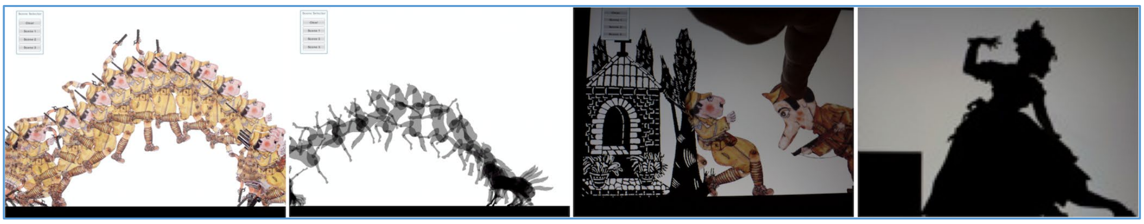
The foundation studies establish that direct touch interaction is possible. This work provides the digital puppeteer with the following insights:

- Collision surfaces, like floors and control objects to push, pull and interact with simulation objects, is an effective tool for virtual manipulations;
- Soft-bodies in silhouette create a playground to morph and re-shape forms in an elastic and expressive manner;
- Soft-bodies, with internal pressure controls, can be given the illusion of breath.

At this stage of the project (2011-2012), I was interested in touch and targeting mobile platforms, on-which soft-body simulations did not perform at interactive speeds. So, accordingly, I rested the idea and took another route. The results are intriguing and playful, and should be revisited as technological performance improves.

3.5 ITERATION 2: MONO-TOUCH

The first ShadowEngine touch prototypes (2010) present the design and execution of shadow and animation silhouette figures constructed of multi jointed rigid bodies. The figures are under the control of a physics simulation. Each part is 'draggable' with a singular point of touch (mono-touch). The prototype runs on a first generation Apple iPad, and was created in the software Unity 3D.[13]



[13] Unity versions: Unity iPhone 1.7.0 (April 2010) and Unity 3.0.0 (Sept 2010)

Figure 21: First touch prototype (a) Karagiozis (b) The Magic Horse (from Lotte Reiniger) (c) Karaghiozis and Morfonios (in the war) (d) Female Figure (after Lotte Reiniger)

Video 3: https://vimeo.com/225988222

Video 4 https://vimeo.com/218785409

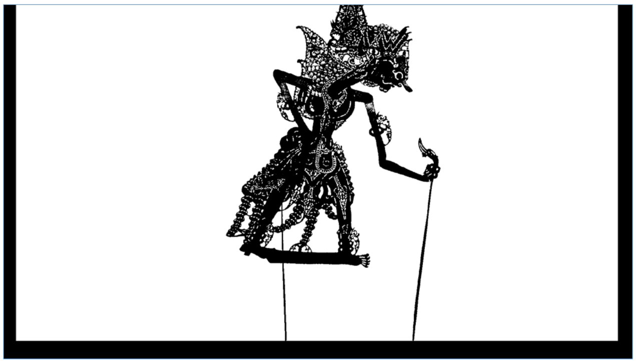


Figure 22: iPad Mono-touch prototype: Wayang Figure (Java) (first generation prototype)

Figure 23: Mono-touch prototype on iPad: The Magic Horse (Lotte Reiniger)

The prototype aimed to:

1. Establish the digital processes involved in producing touch-able digital shadow figures;
2. Set some challenges in the variety of control systems by creating some highly articulated figures;
3. Explore the physics capabilities and constraints in Unity 3D;
4. Explore control device capabilities : in terms of touch and visualisation.

The first prototype established the basic practical methods for getting a figure from a scanned image to an animated, touchable form. Only one point of touch was possible at a time – hence mono-touch. The trajectory was to explore multi-touch, but the coding and approach to do so proved elusive for an extended period of time.

The technical implementation of this workflow has developed as the project progressed. Unity 3D has changed significantly through the duration of the project as new tools and techniques emerged. I capture the full workflow in *Figure 15: Creative methods for digital shadow figure production.*

The choice of figures were significant and require brief discussion.

3.5.1. FIGURE SELECTION

Karaghiozis in Albania by Eugenios Spatharis

Figure 24: Theatre poster: "Karaghiozis in Albania 1940" by Eugenios Spatharis (authors collection).

The initial set of figures were chosen from available printed sources as representative types of jointed shadow figures. A basic criteria was to select samples that demonstrated a variety of assemblies and control methods with contrasting design properties (e.g. coloured/opaque); were drawn from different world traditions.

The two Karaghiozis figures were selected from a set illustrated in Figure 23: from the play "Karaghiozis in Albania", set during the 2nd World War, by the Greek shadow artist Eugenios Spatharis.

Karaghiozis has a characteristic long, independent, multi-jointed arm. The hand part has a control rod attached and is used variously to rhythmically gesticulate, poke other characters, pull the character along, coax the figure to flip from right-facing to left-facing. Only one other figure, in the Greek tradition, has a moveable arm. So as the protagonist, the figure is designed to be more 'expressive' and controllable through a greater range of movement.

Typically, these figures have a second rod, often hinged onto the body at the shoulder—so when the character changes direction the rod is available behind the figure. The lower-legs are hinged and free to rotate at the knee.

The interplay and tensions between one physical rod and the other, and the joints of the figure pulling against the points of articulation create a large scope for movement. My interest is in how these control principles are mirrored and/or transformed in the mono-touch and multi-touch—and the expressive potential afforded.

Rods are important and I assess their inclusion as a form of virtual controller and visual decoration in *4.1 Results from the New Studies*.

The second Greek figure, Morfonios ("Pretty Boy"), has a nasal tone, is more simply jointed—only at the waist. His legs and arms are fixed. Typically, a single rod is hinged to the shoulder, with quite a free pivot. A playing-board, a strip of wood fixed across the length of the bottom of the screen, becomes an important source of friction and resistance allowing the simple jointed character to find controlled movement. Gently push the figure against the playing-board, finding the resistance of the joints and balance point, allows the character to rest, or tilt and pivot. Often, the playing-board has a groove in which a puppeteer can place the lower edge of the figures when they are in repose and not being operated. This frees a hand of a lone puppeteer for a second character.

Traditional figures were often made from camel skin and cut with details providing detailed highlights when viewed in silhouette, but otherwise are black opaque shadows. Modern materials: coloured plastic, coloured silk covering cardboard, allow the translucent colours of figures to be viewed on the reverse of the shadow screen.

In physical shadow theatre, there is great visual subtlety in the colour grading, the focus and the morphology (shape or form) of the resultant shadow. As McCormick and Pratasik distinguish, a combination of careful movement, lighting and depth add to the expressive potential. My question is: how far can these qualities be simulated?

> "In shadow theatre the lighting is an indispensable part of the means of expression, since it exists not to illuminate the figures but to throw their shadows onto a screen. Generally, in Europe, a solitary lamp hung behind the screen and slightly above the heads of the puppeteer was used for shadow theatre. However, the Karaghiozis stage required a whole row of lamps across and below the base of the screen. (oil, candles, acetylene gas, electricity), and, as in the Turkish shadow theatre, the manipulator remained behind the line of lights and pressed the cut-out figures against the screen. In the European tradition, a figure pulled back from the screen would appear to become larger. In Greece and Turkey a very slight movement back from the screen would create a hazier outline which the skilled puppeteer used to give a sense of life to the figures. A figure drawn back only a few inches, would disappear or re-appear almost instantaneously. In general, shadow figures 'entered' the stage from the sides, according to the conventions of other types of theatre, but the symbolic value of the different sides remained very strong." (McCormick and Pratasik, 1998, pg.104)

Wayang Kulit (Java)

The Wayang Kulit image I had available was a simple, low quality, opaque silhouette. It lacks the ornate detailing of the material object, but provided enough detail of the joints, limb articulation and arm control rods and the central, spinal rod to act as a test. Subsequently, the missing lower part of the central rod is an unfortunate omission. I recall 'turning it off' in an early iteration as the colliders were destabilising the whole figure.

Selecting Karaghiozis and Wayang Kulit figures raise cultural issues around the digital remediation of world shadow traditions, especially the radical decontextualisation and hybridisation of traditional forms.

Does it matter when approaching digitisation and re-animation, if a figure is from a sacred, classical tradition or a rough, popular form? Does one figure have a different presence or aura than another?

Is a sacred object stripped of aura (its distinctive or special status) when fusing digital culture with older traditional practices? Can some traditions be more respectfully simulated, than others? I pick up these points in the conclusions.

The Silhouette Figures of Lotte Reiniger

I have poetic reasons for exploring figures drawn from the work of Lotte Reiniger. Reiniger was a pioneer of silhouette animation. She translated her early passion for Chinese shadow theatre into establishing a new kind of silhouette film, making over forty films between 1919 and 1979 . Her work represents a significant and early transformation of live shadow and silhouette traditions into an emerging practice of stop-motion animation. She re-mediated the craft of shadow figure performance into detailed frame-by-frame illusions of movement. Reiniger's work presents a fine analogy for the transformation of a physical craft and gestural performance into a new realm of moving image production: her's with photographic film, paper and scissors, mine pixels, software and real-time digital representations.

As such, Reiniger's work represents a primary example of a proto-media archaeology—a technical encounter where ancient silhouette forms are renewed and transformed through the (then) new media of animated film.

> "Film is motion. … In the silhouette film, instead of the creator playing with drawings, the marionettes play before the camera. These marionettes are not moved by strings or sticks, but constructed *with as many limbs as possible*. They are laid flat on a glass table: thus the light from underneath does not show the joints when the camera looks down on them to take the picture, frame by frame. When the camera is at rest the figures can be *touched* and moved into the next position for a further shot to be taken." (my emphasis, Reiniger, 1936, p.15)

What attracts me here, is the interest in touch controlling complex multi-jointed figures. Can the ShadowEngine enable a real-time simulation of such figures Reiniger painstakingly animated? Can a comparable quality of movement can be achieved?

Reiniger started filming live-articulations of her figures (like filmed shadow theatre). She moved towards a different dynamic, creating early stop-frame animation techniques.

Also, unlike some some traditional shadow figures controlled indirectly by rods, like Wayang Kulit and Karaghiozis, Reiniger's figures are directly 'touched': their very joints and limbs are handled and manipulated into poses and gestures.

The idea of 'direct touch' is re-mediated and re-fashioned through our digital interface.

Lotte Reiniger innovated in her use of multi-plane cameras, parallax scrolling of scenic elements, tinting, colour washes, lighting effects—a whole range of aesthetic, visual extensions to screen space and how these properties are dynamic over time:

> "I have always been fascinated in the problem of artificial movement in films… Of course I like to experiment with different variations of abstract movement for background, lighting effects, etc. But the real sensation for me has always been—and always will be—the discovery of various possibilities of screen rhythm which, to my experience, is the most essential part of film art. … All this business of discovery and experiment was much simpler in the silent days." (Reiniger, 1936, p.15)

I have a desire to create a visual and cinematic space in the ShadowEngine that might facilitate similar dynamics and an exploration of such a 'screen rhythm'. The undulating flow of touch:

slides, spirals, taps and circles are a kind of finger level choreography. I need to continue work to design an approach that is sensitive and nuanced.

For Reiniger, animation is ‘an entirely new kind of puppeteering’ (Reiniger, 1970,p.82). So is touch control.

3.5.2. PRACTICAL OBSERVATIONS

Here is a summary of my practical observations of the mono-touch prototype. It is possible to contextualise these comments with reference to Video 3 and the collected observations in Appendix A-3.

A number of important issues emerged including:

1. The control and simulation of object properties;
2. Upon a touch event, the dragging script effectively creates a temporary 'non-kinematic' object that is attached, via a configurable spring joint, to the object under the point of touch. As the touch-point tracks with a finger move, the spring pulls the rigidbody along and its connected objects.
3. Touch: On the iPad. the Karagiozis figures 'feel' that they lack dynamism. The physics simulations seemed slow and unresponsive to touch. This is in part due to the object scale, mass and the dragging object’s spring strength and configuration.
4. It was noticeable that mouse control seems more responsive.
5. Unity on an iPad (at the time) could not output a video signal to a projector, so projecting a performance from an iPad was not possible.
6. Puppeteers invited to use the interface frequently shook the iPad (to use the gyros and accelerometers), hoping thus to shift the figures in an indirect way. Additionally, users *always* tried combinations of multi-touch gestures and *always* expressed disappointment in the limitations of mono-touch control.

7. They could find interesting poses but felt cramped and 'locked' to the rather small screen.

Aesthetic Qualities of the Restored Image and Silhouettes

8. A noiseless, artefact-free image lacks visual dynamism, especially where the z-order fights draw attention to the layering of elements.
9. Silhouetted objects seem to have greater 'presence' than the coloured figures. They appear as 'coherent' bodies, not just an assemblage of separate parts. The illusion of a continuous contour is only broken when a force stretched a joint out of place and the edges and joints are exposed. Then the figures felt 'unstable'.
10. When the composition of elements is novel or finds a curiosity through a combination of 'attitude', gesture and movement of the figures (e.g. the horse sitting down or placing its hoof on the block), pleasure occurs. Expression can be found then, when the puppeteer cycles from touch to movement to apprehending (seeing) an attitude, and finding a flow between object manipulation, intent through touch or gestural action, object response and resultant image.
11. I have spatial and scenographic concerns around orthographic and perspective projection and the utilisation of screen space. How the touch screen space maps to the performance space is an important consideration.
12. Some physics configurations work, others don't. Overlapping colliders lead to unexpected movement.
13. Physics glitches sometimes totally distract and kill the illusion of the figure. Other times they provide a sense of uncanny animation where twitches and rhythms appear to enliven the characters.
14. Constant gravity on figures that are not constrained to something (e.g. the Reiniger female figure) require a different approach. Further developments could explore what I call the ‘gravity switch’ trick. I switch the direction of gravity from negative Y to negative Z and I place an invisible surface behind the figures for them to rest on. This

radically changes the dynamics of control in the complex multi-jointed figures, for example. The technique mimicks the table based, top-down figure movements Lotte Reiniger intricately reconstructed on her glass surfaces (e.g. see Video 9, Video 11, and Video 13 for examples of the 'gravity switch' effect).

15. The Karaghiozis poster depicting a narrative gave me the idea of systematically collecting figures from a single tradition digitising them and creating a collection of animatable figures. I explore this in Section 3.7.1 Karagöz and the IIM Collection.

Conclusions

My notes from the time:

> "The primary aim was to prove the basic concept: that the 3D models, with UV and texture maps, could work in an orthogonal openGL context, simulating the interactions of shadow puppets in a touch driven environment. There is a rationale behind each of the figures and they all make it to the screen through different design processes. Each character has different rigs. All objects are 'rigid-bodies' and have differently physics properties (configurable joints, hinges, mass, spring and damping properties)"

> "It is very satisfying that the proof of concept works. Playing *can* lead to 'operator emoting', performer flow and rich expressive moments. In terms of performance animation, the combination between direct control and physical simulation (and it has to be said 'accidental physics glitches') is a ripe area for further exploration. For example, in the female figure, the different tension properties and rotation limits of each arm (the right, floppy and dead, the other stiff and pert) - are set to radically contrast to illustrate that expressivity is in part an act of object tuning and configuration. Actually, in the current prototype, the whole female figure is relatively 'unconstrained'. The radical kinetic/visual variation a few settings can make cannot be underestimated." Reflective Notes Ian Grant (2012)

There are numerous ideas and questions here to carry forward:

- Multiple joints and limbs and chains are curiously expressive;

- A varied character choice allows the exploration of different levels of articulation;
- When we get characters together and control them separately (with multi-touch) we can begin to tell stories, and pattern interplay between figures and their environments;
- Using friction boards, objects and floor assist touch manipulation of jointed figures;
- In touch puppetry, in what manner do our fingers replace the control rods?

3.6 ITERATION 3: MULTI-TOUCH, COLLABORATIVE CONTROL, VISUAL DESIGN AND CINEMATICS

The next broad phase of the ShadowEngine project progressed some core elements from the first prototype and had the following objectives:

1. To consider the technical set-up for projection and performance;
2. To enable collaborative control of figures, visual and cinematic elements;
3. To build an effective multi-touch solution: allowing multi-point, dual hand, multi-object and multi-part control;
4. To enhance the aesthetics of the figures and scenographic elements of the first prototype, considering expressive lighting and visual effects;

I'll take each aim in turn and briefly illustrate the problems, solutions and issues germane to each development.

1. To consider the technical set-up for projection and performance;

The design intention was to produce a digital shadow puppetry environment that would be projected. For testing, this would consist of a single projector projecting a single view of the virtual shadow screen either from a tablet, a laptop or a desktop machine.

For performance, multiple configurations were possible. The technology and the options were considered (see Figure 24, Figure 25)

At that time (2010) Unity 3D software on iOS could not support video-out. Apple sold a cable to send the video output of an iPad to an external screen via VGA, but the feature was not widely supported—it was a private API—and would not be officially supported in Unity for three years[14]. In 2012, a third-party solution for Unity emerged but was quickly deprecated when Apple changed the Video-out API in iOS 4. The logic of this meant the iPad had a useful purpose as a multi-touch remote control, but lacked what was needed to host control, image rendering and output functions.

Using an iPad for its multi-touch capability and Unity as a game creation environment still made sense. Unity provided the tools I required - iPad publishing, scripting in Javascript and C#, touch and input libraries, 3D physics (rigid and soft-bodies), model importing and texturing. Authoring such an environment from scratch was beyond my then level of coding skill. I had seen Unity 3D first in San Franscisco in 2007.

Figure 25 llustrates the prototype system I developed to first bring multi-touch to the ShadowEngine. The intention is: each remote iPad runs a puppet controller UI and interface for scenographic changes and effects. The remotes share the same network and uses Open Sound Control to send data to control position, scaling, rotation and other required control signals.

Next, I'll consider the connected aims of remote control and multi-touch:

[14] Video-out and Airplay (wifi network video streaming) support were added to Unity iOS builds in March 2013 in Unity 4.1

2. To enable collaborative control of figures, visual and cinematic elements;

3. To build an effective multi-touch solution: allowing multi-point, dual hand, multi-object and multi-part control;

We have seen the performance control protocol Open Sound Control (OSC) used to support multi-touch digital puppetry in Section 2.3.1 Luís Leite's Virtual Marionettes (2013-present), above and it was an approach I had studied testing Animata (see Video 46: 07:42). In summary you can map the first touch position to a position of a specific joint. The data from multiple touches is quickly encoded and sent across an ad-hoc network.

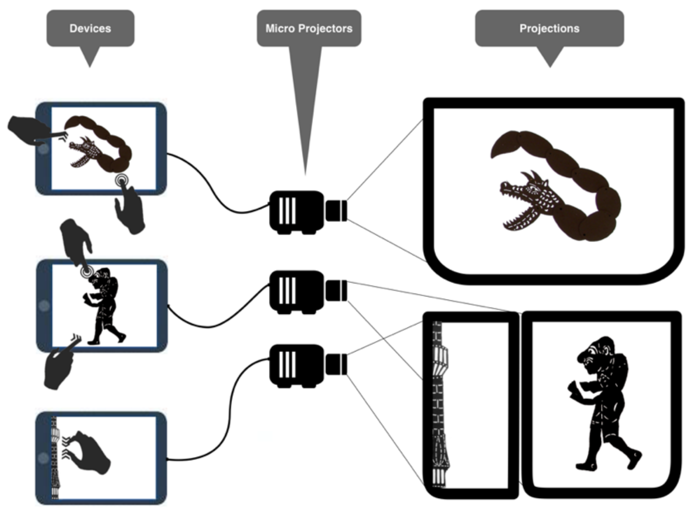


Figure 25: Control, rendering and projection system diagram A: Multiple iPads with direct video-out to multiple projectors.

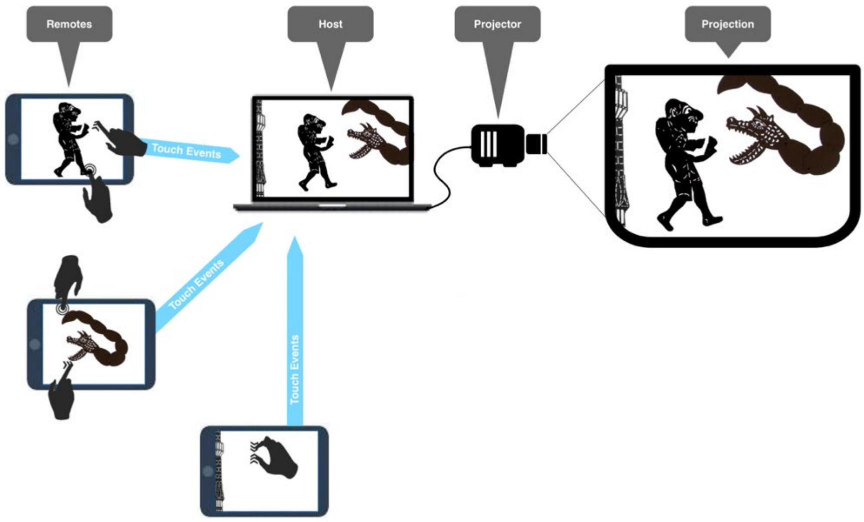


Figure 26: Control, rendering and projection system diagram B: iPad remote controllers to host to a single projector

Leite's and my Animata demo uses a piece of software called TouchOSC and is ideal for prototyping interfaces. From my perspective, I could rapidly build a multi-touch UI to test the figure rigging and jointing.

With my developing programming skills, I understood an open source C# OSC wrapper and got it working in Unity. I achieved collaborative control with multiple iPads and multi-touch control over characters using TouchOSC. Figure 26 pictures the prototype interfaces for controlling effects, camera movements, and multi-touch character control.

The TouchOSC prototype can be viewed working in Video 42 and Video 43 (see appendix A-3). Four iPads are used to control characters, scenography and visual effects.

In this solution, the multi-touch control of characters is tricky. The multi-touch control area is a blank rectangle. The touch-to-figure mapping worked like this: the first touch is mapped to the head control (for example). The second touch to an arm position, the third touch to a leg. The puppeteer is required to learn this order. On a touch, the mapped control would jump to the same relative position on the screen. One touch works okay. A second touch, unless it is in close proximity to the first, makes the physics set up of the character stretch and jump. You can get used to it, but the fixed mapping is cumbersome and prone to physics jitters, joint stretching and total freak out as the jointed object's physics fails.

Though the prototype worked, the multi-touch solution was far from optimal. My instincts called for an interface that mirrored the puppet under control and allowed direct manipulation of controller objects or the character body itself, as in the early mono-touch prototypes.

4. To enhance the aesthetics of the figures and scenographic elements of first prototype, considering expressive lighting and visual effects;

Unity Pro has a flexible architecture and a set of functions for manipulating the output of the virtual camera used to frame and render a particular view of a scene. Like a real-world camera, it can be moved in space, rotated, the field of view varied, zoomed etc. Some properties unique to the virtual camera are the ability to switch between 'projection modes': perspective mode creates an illusion of foreshortening and depth.

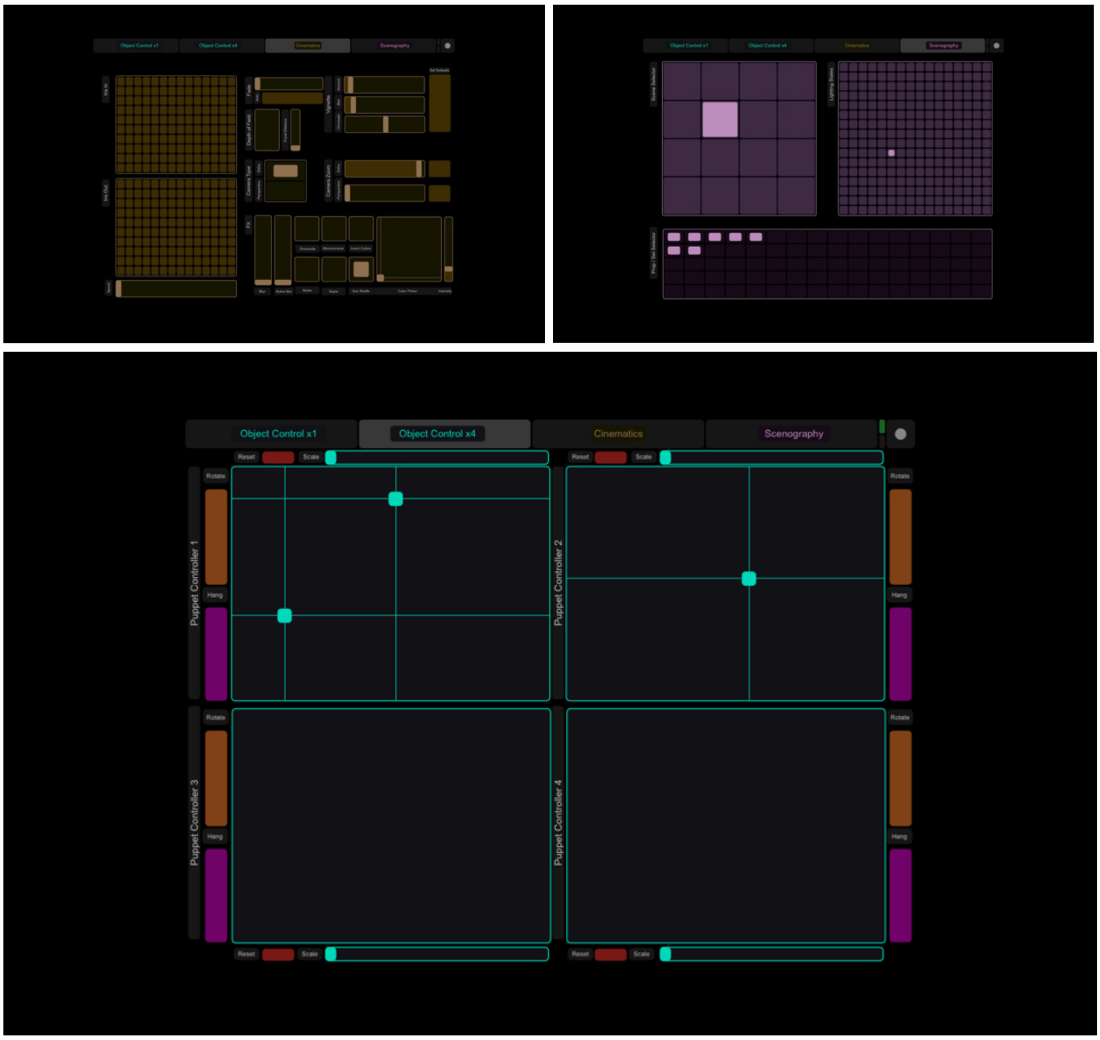


Figure 27: TouchOSC Prototype interfaces for effects, cinematic and multi-touch control

Video 42: https://vimeo.com/115138010

Video 43: https://vimeo.com/115156168

Objects further away are smaller, nearer objects are bigger. In orthographic mode, objects are uniformally rendered at their size, no matter how near or far they are to the virtual lens. Also, the image the Unity camera renders (15 to 75+ frames per second) can have pixel level filters applied to it, like an image in Photoshop, but also across frames in real-time. This can be used to create visual effects and styles.

I created a stack of camera effects and exposed key settings that could be adjusted in real-time using TouchOSC controls (see Figure above). These included: colour tinting, washing out colours, greyscale, inverting colours, image blur, motion blur, anti-aliasing (a kind of softening of edges), distortions, vignetting (an artefact of glass lenses), flares, hot-spots, sun shafts and noise, some are pictured below and can be viewed across the videos, but demoed in Video 42 (from 02:25). Multiple effects can be applied. Third party vendors sell effects that can be used to add to the core functionality of Unity. I chose and applied effects sensitive to the screen worlds of shadow and silhouettes.

Visual Design - Object focus and depth of field

There is depth of field effect that allows the selective focal length to vary and to pull the focus of an object sharp and clear in-focus or blurred: depending on how near the object is to the camera. I wished to emulate the dynamic feel of shadows lifting from a screen (when they turn) and dynamically blur and sharpen. This effect proved elusive, until a future iteration (Figure 28: Wayang Kulit - Depth of field effect). It requires movement on the Z-axis—which is tricky using a 2D touch surface, but not impossible.

Figure 28: Visual design and effects

Visual Design - Colour, greyscale and monochrome

I coded functionality to switch the texture of all the shadow figure objects. I enabled switching between three modes: colour, greyscale and monochrome. This is one of the most dynamic aspects of the ShadowEngine. Seeing the restored figures in these different modes is curious and satisfying. It may be quasi-realistic—that's not the point. The silhouette has a special status as an image.

Charlie Chaplain and Walt Disney (Thomas and Johnston, 1995, p.56) agree the meaning of a character pose or gesture should be clearly read through a silhouette.

William Kentridge suggests there is a distinct mode of (artistic) perception associated with the silhouette:

> "it is in the very limitations and leanness of shadows that we learn. We complete the illusion and, recognising ourselves completing it, become aware of that activity." (Kentridge, 2012)

Figure 29: Wayang Kulit - Depth of field effect

Indeed, rendering colour images as silhouettes draws attention to the outer edge, the contour. Suddenly the morphology of the shape is read as a whole, rather than a sum of parts. The illusion of liveliness is suddenly less fragmented.

3.7 ITERATION 4: DIGITAL RESTORATION AND PUPPET MEDIA ARCHAEOLOGY

This section will indicate how the ShadowEngine, as a whole, is a practical implementation of a fundamental media archaeological method: the digitisation, processing and storage of found elements and their remediation and transformation into new media forms.

This iteration started with three opportunities that gave rise to further developments and a sustained engagement with archival shadow figure objects and related material.

First, a three week residency with award to develop the research at the Institut International de la Marionnette (IIM). I had access to shadow object collections and a library of material. The most accessible collection was a set of 230 Turkish Karagöz figures, stock characters assembled for exhibition in 1982. I detail this work in *Section 3.7.1 Karagöz and the IIM Collection.*

Next: to present the work in progress at an international puppetry conference[15]. Professor Matthew Cohen suggested to look at 'Billy Waters', a galanty show and theatre ephemera as a source of material for reconstruction. At the conference, we were able to evaluate touch and Leap Motion figure control with a workshop of puppeteers, dancers and scholars. See *Section 3.7.2* Billy Waters, the London Fiddle*r.*

Then: an opportunity occurred to use the ShadowEngine to create content in response to a digital story-telling call by Penguin, for the actor Stephen Fry. I describe this work in *Section 3.7.3 The Fry Chronicles*. This project developed a set of features rather quickly, and provided a test to see how quickly and spontaneously work could be built with the ShadowEngine.

3.7.1. KARAGÖZ AND THE IIM COLLECTION

To the archive!

> "In creating such a space for creative exploration and tinkering with either original artefacts or replicas, the researcher will get a first-hand experience of the heuristic difference between studying textual and visual representations of past media technologies and experiencing their performative qualities and limitations in real-life interaction and re-use." (Fickers and van den Oever, 2013, p.274-275)

[15] *Performing Objects*. Falmouth University, UK, October 17th-20th, 2013.

With the generous support of a three week research residency and grant from the IIM, I photographed, processed, and 3D modelled a set of Turkish Karagöz figures, tasvirs[16], and stage properties held in the collection of the Institut International de la Marionnette[17] (IIM). The IIM hold approximately two-hundred and twenty-two Turkish Karagöz shadow figures, props and sets commissioned by Margaretta Niculescu and made by the puppet maker J. Çelebi (the signature on the figures) for a touring exhibition in 1982. Long since in storage, these figures have been carefully photographed and processed to enable them to move again, albeit in virtual space. Many of the figures resemble stock Karagöz 'molds', found in other European collections.

The objects were lit either with a light box or rear-illuminated by day-light when the mounted object collections could not be dismantled from presentation boards.

I researched the figures' identities and the Karagöz tradition through a variety of textual and visual sources. The IIM lacked contextual information on the identity of most of the objects and provided only a few scene descriptions (in French) for figures that had been collected into vignettes to display stories and scenarios.

I present the full documentation of the Karagöz shadow figures as a separate monograph in Appendix B.

[16] 'Tasvirs' are objects that are mostly motionless, though some are partially animatable.

[17] Institut International de la Marionnette, Ecole Nationale Supérieure des Arts de la Marionnette (ESNAM). 7 place Winston Churchill. 08000 Charleville-Mézières, FRANCE.

Figure 30: The Karagöz Collection from the Institut International de la Marionnette. Digitised for digital puppeteering 2015.

To avoid decontextualisation, it is necessary to represent, with more specificity, the contexts of the figure. I still had a motivating interest in the technicity of the objects and their affordances as animateable figures: finding appeal in some of the more intricate figures.

A selection of the figures have been used across the iterations of the ShadowEngine, and can be viewed in the following videos:

Figure 31: Karagöz and Hacivat – Experiments with Rods

Video 28 https://vimeo.com/230807432 Video 29 https://vimeo.com/230806699

Video 30 https://vimeo.com/230806776 Video 31 https://vimeo.com/230805414

Video 32 https://vimeo.com/230803662 Video 33 https://vimeo.com/230802135

Figure 32: Multi-touch controls on IIM Bird

Video 22 https://vimeo.com/247689825 Video 23 https://vimeo.com/247689499

A close assessment of the IIM Bird figure appears in Iteration 5 and the summary of results. Also, Karagöz and Hazivat appear in a set of videos exploring how representation of the physical control rods can work in virtual space. In summary, they are awkward as controllers, but visually appealing.

3.7.2. BILLY WATERS, THE LONDON FIDDLER (C1850)

Billy Waters was a one-legged fiddler who busked a small living outside the Adelphi Theatre, London. A former slave, Billy Waters traded servitude to join the British Navy. He was represented in William Thomas Moncrieff's entertainment "Tom and Jerry, or Life in London" (1821). He died, in 1823, in poverty at the age of 45. He was later cast as a statuette figure in porcelain by the Staffordshire and Derby potteries. He entertained crowds outside London theatres with his violin and dancing.

H.G.Clarke and Co. published a range of Galanty Show kits in the series 'The Galanty Showman', including "Billy Waters: The London Fiddler" (The Galanty Showman No.18).

Video 40 presents a documentation of the digital media archaeology involved in restoring such a galanty show (a miniature animated shadow play) from ephemera published by H.G.Clarke and Co. circa 1850. The play-text of "Billy Waters: The London Fiddler" includes woodcut illustrations of the silhouette characters and sets, and a folded sheet of figures and props to be cut out and mounted on cardboard. I had access to a PDF of the play-script held in the State Library of Victoria, Australia.

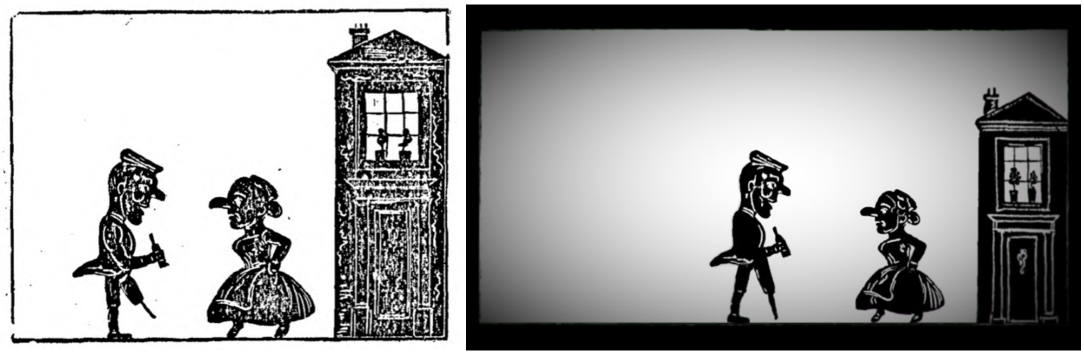


Figure 33: Billy Waters, The London Fiddler. Before and after digital restoration

Video 40 https://vimeo.com/232265796

The characters and sets were reconstructed, via digital painting, from a poor scan of a damaged one-penny piece of ephemera.

We see the characters move for the first time in 150 years.

3.7.3. THE FRY CHRONICLES

Figure 34: Digital Storytelling "The Fry Chronicles", Ian Grant 2014.

Video 43: https://vimeo.com/115156168 Video 44: https://vimeo.com/114836492

Video 45: https://vimeo.com/114829064

How quickly could the ShadowEngine be re-purposed, with different figures and different scenic elements, for digital storytelling?

A project opportunity arose. Actor, technology fan and author Stephen Fry and his publisher, Penguin, launched a digital story-telling challenge, with a task to re-tell elements from Stephen Fry's memoir, "The Fry Chronicles" (2014).

There are several features of the submission to Penguin that warrant brief remark:

- We had multiple touch surface/cinematic controllers enabled by Open Sound Control. Multi-touch in this period of the project had not been refined. The TouchOSC approach was used.
- We used combinations of mouse, touch (iPad) and keyboard control;
- Multiple characters can be controlled simultaneously via four iPads (maximum of sixteen characters);
- Keyboard keys switched scenic frames;
- Enhanced cinematic and visual effects (smoke, flames, manual and automated iris pulls and fades to/from black);
- Attachable/Detachable objects;
- Objects with automatic animation qualities (see Video 45 at time 04:04)
- New characters were created quickly by removing the heads from the Billy Water cast and replacing them. What is poetic about this is: in analogue puppetry replacing heads onto stock bodies is a puppetry basic. In shadow theatre removeable heads are quite common. In Karagöz, there is a notion of a mold puppet—a stock figure easily replicable, with interchangeable parts. What this means is: I could rig a stock set of figures with different limb configurations and simply replace textures—near automating

character rigging; Enhanced cinematic and visual effects (smoke, flames, manual and automated iris pulls and fades to/from black);

- The use of the Unity editor (which at this point in the project was free[18]) in a set-up for performance with custom editor buttons. You can see this in use in Video 42 at time 00:58. I'll expand on this in *Section 3.7.4 Surviving performance conditions,* below.

3.7.4. SURVIVING PERFORMANCE CONDITIONS

The broad aim of creating a stand-alone iPad application on multiple devices remote controlling a client application, still wasn't complete. The working prototype of that system arrives later and is detailed in 3.9 Iteration 5: Movement and Control.

I found a way to use the Unity Editor as a tool to help in the live performance of characters. Such an approach is flexible and allowed rapid iteration and development. On connecting a projector it becomes an extended display, a second non-mirrored monitor, onto which the ShadowEngine 'game view'—the rendered camera output window—could be positioned. The rest of the editor could then be used for selection, mouse control and on-the-fly configuration.

[18] Unity Technologies deprecated Unity *Pro* with image effects, advanced networking and iOS publishing (costing >£1000) and bundled all the functionality, previously sold for a premium, in the free community edition.

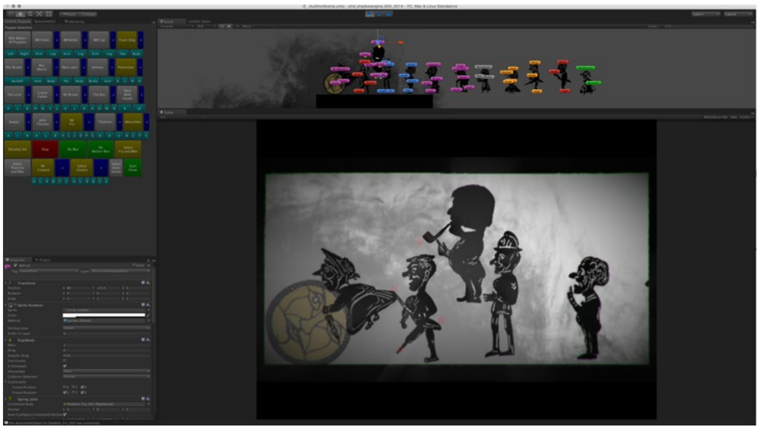


Figure 35: Custom buttons and the use of the Unity editor as a playing space

In an unplanned route, the ShadowEngine was being used to produce machinima: live performance control made in a game engine destined for distribution on video. I had always considered the ShadowEngine as a live-performance tool.

Also, I need to critique the puppetry and the quality of animation. Most of the manipulation we see in the video documentation lacks a sense of control and purpose. It is what is known by puppeteers as 'dolly waggling'. In subsequent iterations—when multi-touch is re-implemented—I do find a higher quality of expression and get to a point where there is a greater sense of control (for example, see Video 30 and Video 34 at time 14:01).

Despite my critique, the work got a favourable reception. Sir Tim Berners-Lee, Stephen Fry and Will Gompertz were on the review panel and gave the following feedback:

> "The ShadowEngine is such a creative idea! We loved the original use of source material and the artistic direction of this piece. Shows a real creative flair and a talent for storytelling, particularly in the bringing to life of all the various references and inspirations. The show was very enjoyable!" Sir Tim Berners-Lee, Stephen Fry and Will Gompertz (2015)

3.8 INTERLUDE: CRAFTING THE DIGITAL HAND

Figure 36: Lotte Reiniger's Hand

Video 27 https://vimeo.com/232826190

I became absorbed by Lotte Reiniger's meticulous attention to detail and how she constructed silhouette outlines from multiple overlapping parts:

> "The silhouettes had to be quite flexible in their movements and were built from sometimes up to fifty different pieces, held together by thin lead wire. If a close-up of a character was needed, another, larger silhouette of head and shoulders had to be constructed." (Schönfeld, 2006, p.176)

The coherence of the hand shape depends upon the subtle movement of overlapping sub-parts. For each part, movement is constrained so as not to break the edge 'silhouette' of the resulting form.

Unlike the IIM bird figure, which has clear 'chains' of objects in the neck and legs, rooted to the body in the centre, the hand object has multiple centres, about which several linked objects pivot.

> "How intelligent are your hands? Do you even use you hands to write now or just type? Has 'hand intelligence' been moved into just the fingertips? Tip, tap, touching screens and buttons. Funny, but the incredible ingenuity of the hands has now rendered our hands obsolete. Almost. The puppeteers of your community, and indeed all over the world, are fighting this global epidemic." (Rollins, 2015)

I believe this interlude study has significantly influenced my thinking about shape, dynamism and liveliness. The systematic experimental comparisons of interactive methods (touch and hand motion capture in Video 27) synthesised expert design (on the part of Reiniger), effective decomposition and recomposition, effective rigging and grouping of controllers . The accidental discoveries of digital ombromanie with 3D hand representations within and the quirks of hand motion capture made this study exemplary of the kind of digital shadow puppetry I wish to make. Touch works. The mouse works. The scroll wheel works. Hand motion detection works. This is a fragment but points at the future directions these methods should take.

3.9 ITERATION 5: MOVEMENT AND CONTROL

Figure 37: Iteration 5: Rigging comparison architecture, UI and OSC Remote

As the iterations progressed and most of the important interactive capabilities, i.e. multi-touch, worked and were robust, I needed a systematic way to compare and contrast the different control methods and rig styles and synthesise the methods explored into a form upon which to draw my conclusions.

The iteration also completed two additional software features necessary for final evalution: robust multi-touch and an effective architecture for sending multi-touch and control signals over OSC.

So, Iteration 5 was designed with three objectives:

1. Take three contrasting shadow figures that existed in earlier prototypes. Rig them with each of the different control methods explored to that point, and document their use to supply visual evidence about how they move and respond to touch;

2. Iteration 5 produced paired versions of the ShadowEngine: one called ‘remote’ that ran on an iPad as a remote control sending/receiving OSC data and another as a client on another machine receiving OSC data. For the first time, a figure could be seen and

controlled on the iPad and the movements mirrored on the client machine and projected. This differed from the previous prototype OSC setup that used TouchOSC: that did not have a visual representation of the manipulated object, this solution allows the puppeteer to manipulate the figure on the touch screen;

3. Build a UI to replicate the functionality we had in TouchOSC, and with a persistent data store to save state and preferences.

Objectives 2 and 3 were achieved and can be best explored in the software Appendix C – Code Repositories and viewed (briefly) in Video 41. I do not focus at length on them here because Objective 1 is aligned to the practical areas of creative enquiry:

> How can touch and gestural interaction facilitate expressive puppeteering and collaboration in digital shadow play?
>
> What are the most effective methods to create and evaluate digital shadow production and play?

How do rig and controller designs enhance or inhibit expressive animation? The approaches consider the hierarchical structure of the figures and controllers, the use of physics and the type of kinematic solver used in the movement goals.

To properly evaluate the relative merits of mono-touch and multi-touch puppetry combined with Physics Based Animation (PBA), I formed the view that I needed to test the solutions in action.

I selected shadow figures from across all iterations of the ShadowEngine, placed them in the ShadowEngine Iteration 5 and proceeded to play with the system and capturing videos. I readied the videos for analysis in a tool designed to help compare the videos of movement and control, playing multiple videos simultaneously, side by side, taking notes. These notes are recorded in Appendix A-3.

The commentary builds into a self-ethnography of the creative process and a hyperlinked reflective commentary to accompanying the video documentation. It is too detailed to include in full in this text, but provides key terms, emergent themes and ideas that have been extracted and have shaped the analysis.

The themes are presented in the next *Chapter Conclusions*, *Section 4.1 Results from the New Studies*

4. CONCLUSIONS

4.1 RESULTS FROM THE NEW STUDIES

4.1.1. COMPARING MOVEMENT AND CONTROL APPROACHES

I devised a qualitative method and tool to assist the structured observation of the 'unstructured' video data. It involves a tool for (re)viewing, coding/indexing and comparing sub-sections of the videos.

As stated above, I needed to collect and compare movement across the three rigging and control modes that had been established in the prototypes. In summary, these are:

- Direct Control with Physic based animation (PBA)
- Spring Networks (with PBA)
- Forward and Backward Reaching Inverse Kinematics (FABRIK)

In addition, there is a small set of experimental examples, interspersed in the videos, that use a gravity switch and are a variation of direct control:

- Direct Control with Physic based animation, a gravity switch and a friction surface

I created a video comparison tool (A-2 Video Comparison Tool[1]) to support the method, and assist the structured observation and analysis of the captured videos.

I grouped videos into the following categories, by puppet figure: Prototypes and FABRIK, Wayang Kulit, Karagöz Bird, Reiniger's Hand, Rods - Karagöz figures, Early Touch Prototypes. Within each category, the assembled videos could be reordered, played/paused (simultaneously if required), randomly accessed via coded chapter markers (identifiable by colour). This was to aid review, make associations and theorise the re-current themes.

The observations are recorded in the Appendix A-3 and were coded. These codes were then fed back into the video comparison tool as further 'Chapter Keywords', aiding further structured comparisons.

4.1.2. DESIGN FOR EXPRESSIVE MOVEMENT

The discussion below synthesises the themes, re-current issues and insights across the video observations into short summative statements.

Rotation methods

Across all the iterations finding a method to turn a figure through 180º on the Y axis in order to flip the direction the puppet was facing proved elusive. The most successful occurances happened in the first, early prototypes where the figure was a full 3D model, not a sprite or a 2D form. In order to rotate, the figure had to be unconstrained on the Y-axis (allowed to rotate), then pivoted on the friction board, with a downward swiping gesture from a carefully targeted swipe. Once practiced, the rotation had flow, dynamics and a sense of shape and spatial integrity. You could effect a similar action with multi-touch: anchor a touch around the bottom

[1] See http://daisyrust.com/shadowengine/thesis/appendices/a/ and on the submitted media.

of a figure, then swipe from another corner, diagonally. This worked consistently (once learnt) with the Wayang Kulit figure. Spring network controls (especially Bird and the Wayang) allow physical simulations to continue when the figure rotates. This leads to satisfying secondary action. When subtle, this feels effective. Sprite based 2D figures flip/rotate in a most unsatisfactory way. Triggered by a double tap/click, they either rotate by negative scaling the object on the X-axis or a tweened rotation. This occasionally works. But when it fails it is as if the physics simulation suspends then re-animates, create a very jerky action and loss of fluidity. FABRIK objects rotate in a very still and undynamic way. In Video 5, the rotation proof of concept, the figure rotates in a convincing way. It is in part due to the form of the figure: the trailing tail and the way the controllers connect. In some respects, successful rotation seems dependent on all features of a figure: its underlying geometry, the physics configuration, the hierarchy of controllers, and its morphology—and the chosen rotation method adapted accordingly.

Scaling Methods

Scaling works in the spring networks and FABRIK multi-touch setups (see the Karagöz bird Video 22 and Video 23 – select the 'scaling' keyword in Appendix A-2). The pinch to zoom gesture on the main body of the figure seems to work, but can get accidentally triggered. This is due in part to the small scale of the iPad screens. Once a figure is scaled (smaller) interaction becomes tricky. I coded the action not to scale the controllers, which lets translational movement happen but fine interaction with the tiny figures are tricky. I note that using two styluses rather than fingers helps precision in scaling and translation gestures. The stylus are analogous to tangible rods for a virtual figure.

Translation Methods

There are qualitative differences between physics based approaches (spring networks and direct manipulation) and the FABRIK rigs. FABRIK figures are highly tolerant to excessive chordic stress (pulling apart the controllers). FABRIK has a smooth, controlled quality. The user feels in control. One has to fabricate mimetic physical responses (like bounce, spring or recoil) with the tempo and rhythm of the finger moved. Multi-touch is very stable in FABRIK (this is nicely illustrated in the prototype section with Video 6, Video 7 and the Karagöz Bird in Video 23).

Movement and control - Spring networks

Touch interaction with spring network rigged figures creates wonderful instances of secondary motion, glitch, a sense of breath and liveliness. This is exemplified in Reiniger's hand (documented in Video 26 and Video 27).

> "Real puppets often incorporate a lot of 'secondary motion' into the design. Long fur or hair that drags behind a motion, or arms that dangle and swing, can add life to a puppet. Even a puppet that's only going to have one hand controlling it, and thus not a lot of direct control, can get a lot of `free' motion from physics this way. We can use similar tricks with our digital puppets." (DeGraf and Yilmaz, 1999)

Reiniger's hand exemplifies the readiness of figures in the system to be mapped to other modes of interaction (e.g. Leap Motion, Eye-tracking). To do so is quite straightforward and represents a flexible and modular design.

Movement and control - Forward and Backward Reaching Inverse Kinematics

As noted FABRIK is smooth, predictable and stable. I posit we need another mode: a blend between the potential unfettered chaos of spring-network control and the stability of an IK/FABRIK solution. Such blended system are known, but were beyond my technical skills to implement. My instinct is, the system requires a method to dynamically switch between the models of rigging and control or, ideally, have both and blend the results.

Movement and control - Direct Control

Direct control requires futher study. All the videos in the 'early touch prototypes' work very well with mono- and multi-touch interaction. Figure control is responsive. Rotations on the XY plane are stable. Multi-touch just works with gestures like 'anchor and flick'. Limbs can be readily 'picked up' with a touch. Two many simultaneous touches (I'd suggest more than three) become an ergonomic challenge for the puppeteer. Dual hand control (with single index finger touches) is intuitive. Dual stylus control is also intuitive. A late experiment with the 'gravity switch' produced some very interesting results. The implementation requires finesse, but the flow and floating feeling is qualitatively different from a straight ahead spring-network or physics based animation. The 'gravity switch' captures can be viewed in Video 11 (at 05:28), Video 9 (at 01:32), Video 13 (at 04:40) and Video 15 (at 06:13)

Figure calibration: weight, friction and other properties

Analogous to the carefully lead weighted figures of Lotte Reiniger, adjusting the physics properties of a figure significantly changes its affordances to expresses through animation. The balance of mass distribution through the connected bodies in a figure radically effect the way a figure finds its repose, balanced position and stillness.

Rigging: Controller Parenting, Sets and Hierarchies

Great movement control can be achieved with carefully designed controller hierarchies. The Wayang (spring-network rig) exhibits imaginative parenting—effectively simplifying a control rig, e.g. two arms can be moved with one controller. Reiniger's hand (spring network) does a similar grouping of controllers: four fingers with one controller, while still retaining individual control of the digits.

A useful addition to the configuration and setup would be a UI that allows for run time creation and editing of controller hierarchies and sets: a method for dynamic parenting.

Friction and Collision

The 'friction board', the floor (in most cases) is a major asset in finding and achieving poses and movements with the figures. I moved on too quickly from the soft-body experiments where interactive colliders were used in quite an innovative way. Having moveable colliders ‘in-world’ and using them to manipulate objects is a rich area for further study.

Accident and Glitch

There are plenty of examples in the video documentation of glitch working in a productive and destructive manner. Serendipitous discoveries are part of the creative journey when exploring the expressive potential of a puppet figure or object. The same seems true in the unstable worlds of physics simulation. Sometime figures self-destruct (see Video 33: Fails, glitches and accidental motion).

Rods

There is something skeuomorphic and wrong about trying to touch an image of a rod with a finger. Then send control impulse through that rod to a virtual object. Though it is fun to try. It seems absurd to simulate rods, and attempt to hold those rods with a finger touch or a stylus (actually two points of contact are required to rotate a rod on the XY plane).

Visualising rods and using them decoratively is certainly complementary to the emulation of shadow theatre. But it does create a confusing image (for the puppeteer) trying to optically sense the source of an impulse to move.

For reference, the videos that focus on ‘rods’ working and glitching are: Karagöz and Hacivat: in Video 28 , Video 29, Video 30, Video 31, Video 32, Video 33, and Wayang Kulit in Video 15.

4.2 CRITICAL PERSPECTIVES

Achievements in the ShadowEngine

I am proud with my accumulated efforts to test and establish digital methods that enact restorative work to make dead puppet figures move. Restoring performances to the "Karagöz" figures, the "Billy Waters" fragments, Lotte Reiniger's 'Hand' represent sustained and informed acts of digital puppetry and technical skill.

I am pleased to finally conquer coding problems, like writing a robust multi-touch and touch visualisation class, and pulling together the worlds of coding, computational design, puppetry and shadows. I consider the ShadowEngine a success: it produces rich imagery and movement. I enjoyed the concrete, practical problem identification and solving. Locked in the code repositories are many personal eureka moments.

The abandoned soft body experiments may be the first I return to. I didn't have enough tricks or transformations (except Video 35) that measure up to the playful distortions of the inflatable Stanford bunny. I imagine a space that combines approaches across the experiments and iterations, and takes time to discover new hybrid approaches from the existing techniques.

> "One of the most ingenious aspects of the shadow theatre is transformation. Tiny hinges and pulleys allow features to flip, rotate, or shift their forms suddenly or serenely. In the blink of an eye a lady can turn into a monster, a demon suddenly grows, or, more subtly, faces change from innocent to suffering" (Princeton University Library, 2009)

The transformational aspects of shadow theatre, via trick puppets, is presented in the Karagöz collection, in Video 35. The rotating upper body part transforms a women to a donkey.

Deficits in the ShadowEngine

I held at the beginning I needed to test the technical system through performance. The complexity of getting things to work as envisioned meant that when actually performing with the system, the task stretched its capabilities and, paradoxically, progressed the development. Still, I didn't fulfil what I thought performance might be with the system. There is evidence of performance and expressive gesture in the video documentation—but those moments were hard won.

The workshops with practitioners and tests with students, annotated earlier, helped refine techniques but didn't equate to the sense of performance I had planned.

For all the useful focus on touch and movement, the absence of sound, voice and sonic augmentation began to worry me. Our perception of weight, of character, the dance between puppet and performer, are all lessened in an environment devoid of sound.

Digital shadow theatre is not all about the visual perception of movement, but the enlivenment of all our senses.

Fetishising the Technical Processes

At times the work may veer towards an over elaboration of the technical processes of interaction and approach what might be seen as technological fetishism. But, I assert, the absorption in technical media occurs only insofar as the sensed tactile and gestural acts serve the processes of animating a variety of forms. Building the animation system and coding is an absorbing technical act, but the focus is geared towards the co-creative acts facilitated by the systems in use and in performance. Watching participants use the ShadowEngine gave me the following insight: as a developer coding the software my focus was on A. The next imperative was B. Once a technical issue or bit of architecture was functional, complete and tested, or a content asset made, the next job was C. In a workshop, I saw participants lock their focus on the potential of

A. They sustained explorations of movement, as dancers, puppeteers and animators, giving themselves time and absorption in the new media figures that I infrequently gave myself.

Coding, like performance is reflective practice: "innate to performance is the ability to reflect on what we are doing while we are doing it. I practice, and I reflect upon practice in infinitesimal loops." (Kozel, 2010,p.208)

A concern about the loss of materiality and depth

Puppetry is very much a physical, material media: lock puppetry within computers and digital forms then one of the sensorial, experiential aspects of material play is—potentially—lost. The vitality, imagery and dynamism of shadow theatre thrives on the interplay between the assumed virtuality of the shadow figure as shadow and its presence as a tangible object. Occasionally the ShadowEngine demonstrates analogous dynamism—but the simulation is lacking a sense of depth and variable focus. The easy dynamism found by varying a tangible shadow figures proximity to the screen, eludes the digital simulation, constrained to a depth-less plane:

> "flattened, geometricized, ordered, it is anti natural, anti mimetic and antireal. It is what art looks like when it turns its back on nature. In the flatness that results from its coordinates, the grid is the means of crowding out the dimensions of the real and replacing them with the lateral spread of a single surface." (Anderson, 2006, p.3)

The same concern is expressed by Kentridge, but he suggest the planar constraint should be made a feature of the semiotic of the lateral space:

> "With shadows, the forward movement of an image becomes problematic. You have a light source and you have an object blocking the light. As the crowd moves forward towards the light, it's shadow gets larger and larger, until it obliterates the entire screen. Its forward movement has very limited forward flexibility. Whereas, with the lateral movement, while it does reduce the mass to an itemised list, it does enable a continuation. A sense of an ongoing procession" (Kentridge, 2012)

A concern about digital obsolescence

Given cultural 'preservation' is the justification for many experiments in digitising traditional shadow figures, it is ironic how many technologies I've used have become obsolete during this project: the first generations of iPad, the Eye-Tribe, certain programming language features deprecated in Unity 3D. It is an irony that the deadest of 'dead puppet media' and near-living puppet traditions seem more durable than the computational media and tools chosen to enable creative acts of preservation.

4.3 SUMMARY

The ShadowEngine projects shifted continuously over the duration. Software updates, opportunities presented themselves, time pressures required rapid solutions. The original enquiry refined and focussed on comparing three approaches to rigging digital shadow figures for different touch and gestural interactions and finding a structured way to compare the qualities of movement.

I succeed in a prime media archaeological intent:

> 're-animation using technology to unlock the life of archival puppets' (Watson, 2014)

Through digital processes I have helped preserve—not only the visual properties of several sets of shadow figures—but also a version of their kinetic properties and expressive affordances. These may be transformed into something new—but there is a level of fidelity in the analysis and deconstruction of movement potential via digital processes.

In terms of the creative aims:

To devise different methods of character control and rigging for expressive real-time animation;

I have systematically presented alternative modes of control and rigging and devised a video documentation process to help review and compare expressive, touch and gesture based movement.

The ideal configuration is to have a diversity of modes of control and rigging approaches available for each figure and a quick way to switch, or blend, between them. I begin this in the GUI that switches between comparisons of direct control, spring-networks, IK and FABRIK rigs. An open system where these control approaches can be applied to any figure would be optimal.

To explore interactive dynamics and user interaction to create emergent character movement and expressive figure behaviours;

After the initial software was developed and key problems solved, I was in a position to test a number of approaches to physics based animation and user interaction. The work is graceful at times and has been thoroughly documented and evaluated. Nothing can be a surrogate for the hands on experience of using the system. It is open source and shared on github.com[2].

To draw on the aesthetics of the silhouette and techniques of shadow theatre.

With the sustained work on the Karagöz figures, 'Billy Waters' and Lotte Reiniger, I have made a contribution to answering the question of what happens to old media forms in the face of change. I've presented examples of remediation in action.

[2] Ph.D. Project Github Repositories: https://github.com/iboy/PhD.

The study values accidental discoveries—serendipitous benefits of open-ended practical exploration. For instance: the extensible nature of the control system means novel input—other than touch—can provide exciting potential for accessible user interaction, e.g. with gaze duration and eye direction. The study also identifies limitations including the rate of software change and obsolescence, the scope of physics-based animation and failures of simulation.

The presented work offers the following contributions to knowledge as a response to the areas of creative and critical enquiry:

1. A software system which enables touch control, gestural and a variety of other forms of input, to be mapped onto a range of digital shadow figures: characters and props of varying complexity from various world shadow traditions.

2. The software system enables a level of cinematic and sceneographic control that presents a collaborative space for digital storytelling;

3. A puppeteerly approach to animation control that is visual, tactile and collaborative;

4. An exploration of a variety of control methods using combinations of physics simulation and interactive control;

5. An experimental base for further interactive performance animation experiments expanding traditional forms of shadow puppetry and abstract visual performance;

6. A discussion on the restoration of past puppetry forms and the interplay between old and new. This includes creating an extensive photographed collection of archived Karagöz shadow puppets restored into kinetic play through digital processes involving image preparation and character rigging;

7. A discussion about the expressive potential when puppeteer skills are translated into real-time performance animation.

8. A (re)discovery of the aesthetic power of the silhouette. In digital shadow theatre the dynamic play of material and morphological properties equates to a rediscovery of the expressive properties of the silhouette in digital form. It is at once surface but modelled in a space where dimensions are fluid and procedurally variable. Expressive acts emerge from simulations of Newtonian physics and the dance of agency: a dance where there is a regulatory shift between (re)cognition of movement and the lively touching of virtual and real objects.

   The real-time play allows the emergent, accidental, often poignant action to be created and perceived. Eg. The impaling of Hacivat on his own rod (Video 33, 01:06)

Both digital shadow puppetry and shadows have an intertwined relationship to the material and the virtual, to the relations between the object and the image.

Also, fundamentally, computer puppetry performs a grand act of simulation: of worlds, light and dark, material properties of physics, shape, form and colour all mathematically and algorithmically described.

The connections between my digital work and the aesthetics of shadow theatre are very active and traceable. Such remediation demonstrates a basic state of the braiding between old and new media. Puppetry—with all its presumed primitivism—and technology are deeply intertwined.

4.4 FUTURE DEVELOPMENTS

There is something personally compelling about the digital creative processes explored in the ShadowEngine projects. I have been occupied over a seven year period, and I am still as absorbed in discovering the acts of touch puppeteering and animation possible using the system. This absorption and the playfulness it facilitates is a major mark of its success.

Like many software projects, it is hard to resist continuous tweaking and imagining features on an inexorable drive to improve figure interaction and response, and add greater levels of functionality.

I do have a list:

- A recording function to capture touch data streams and replay and overlay controls (like sequencing movement);
- Improve the GUI and the remote capabilities; A functional and elegant user-interface to control each animatable figure. Built on radial menus (that are gestural) one could unobtrusively configure and control meta-functions of characters. I wish for immediate control over sets of parameters per object (e.g. Collision, mass, spring, damping, friction, controller sets).
- The animations results are satisfying enough to continue to digitise shadow figures from other traditions. There are options to continue the broad digitisation approach and work on figures from other traditions. I started to look at Chinese figures from Chengdu (Video 34);
- Auto-rigging and automated figure setup;

Getting figures to move with flow, grace and purpose is only one albeit important part of shadow theatre, devising performances, vignettes and sketches with, voice, dance and live music are also planned.

I have an opposite desire, years staring at pixels may drive me headlong back into analogue forms. Better than that, a hybrid interplay between the tangible and intangible.

The study established a survey of digital puppetry, and set a future research agenda beyond shadow puppetry to other forms. Work may proceed to digitise, rig and create collaborative and web-mediated touch-based motion control systems for 2D *and* 3D puppets. The present study thus provides a solid platform to restore past performances and create new work from old, near forgotten-forms.

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APPENDIX A – VIDEO PORTFOLIO

A-0 INTRODUCTION

Appendix A consists of three elements: (A.1) an online portfolio[1] of annotated videos, documenting key aspects and developments of the work. (A.2) a video comparison tool providing an environment to code and compare movement qualities between different rigging and control approaches. (A.3) an annotated list of all the videos, including links, descriptions and a set of observation notes hyperlinked to chapter markers. The time-stamping system was devised to allow systematic review and structured observation of related phenomena across the collection of videos. The video portfolio works best online. However, the printed time-stamps and chapter markers in most of the archived videos allow off-line exploration in accord with the demands of a submitted thesis.

1 https://vimeopro.com/iboy/practice-portfolio. The video portfolio is archived on the accompanying media.

A-1 VIDEO PORTFOLIO

Video Portfolio: https://vimeopro.com/iboy/practice-portfolio

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Video 23 Movement and control - FABRIK - Karagöz bird figure 230

Video 24 Movement and control - FABRIK - Karagöz bird figure - inverted - glitch 233

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Video 45 The ShadowEngine - Process......272

Video 46 Foundations- Animata and Photoshop. Mesh-based image warping tools for real-time animation......276

A-2 VIDEO COMPARISON TOOL

Video Comparison Tool: http://www.daisyrust.com/shadowengine/thesis/appendices/a/

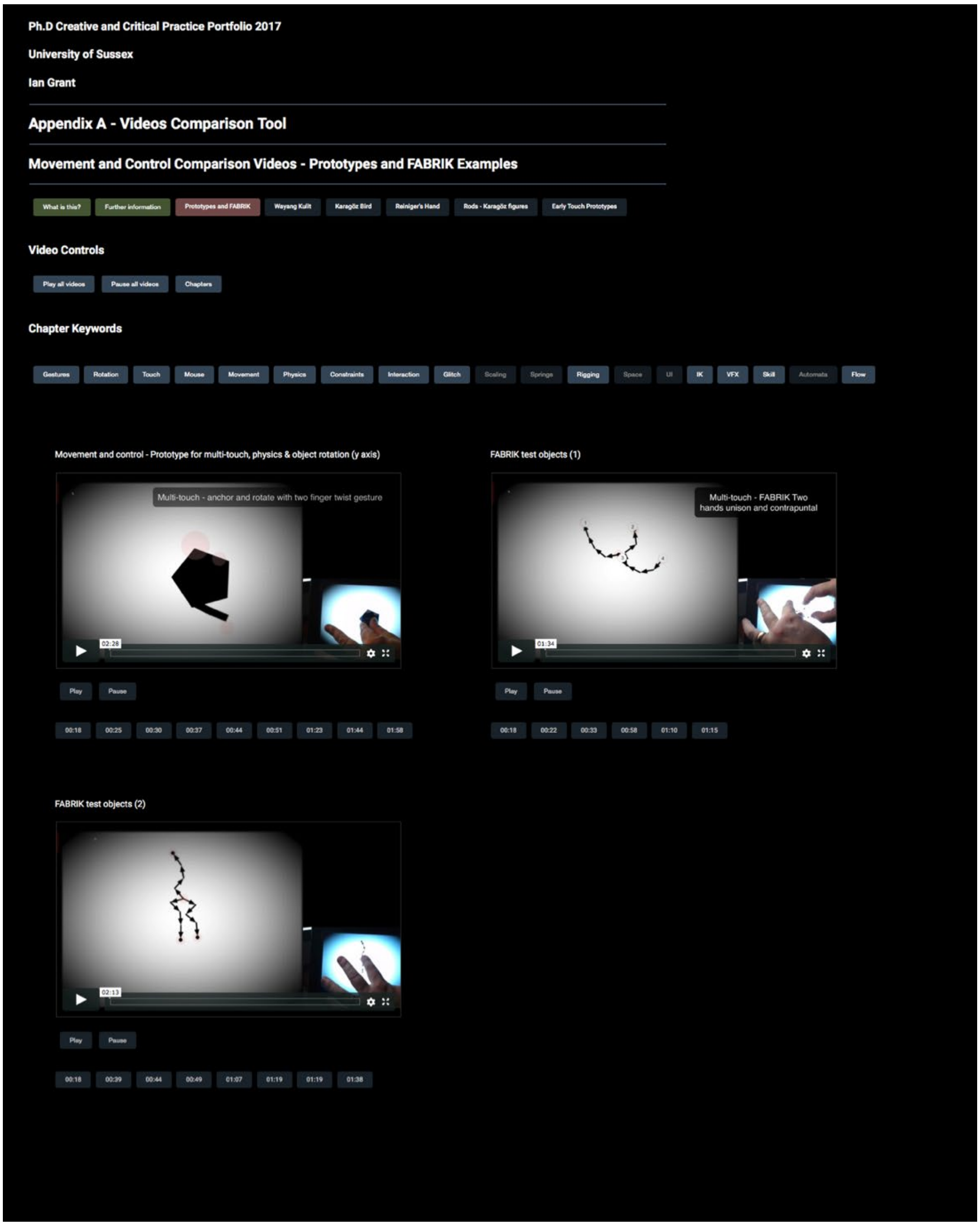


Figure 38:Appendix A-2 Online Video Comparison Tool

Appendix A-2 is designed to assist the comparison of video captures that document different touch based digital puppetry control and movement methods across the ShadowEngine project.

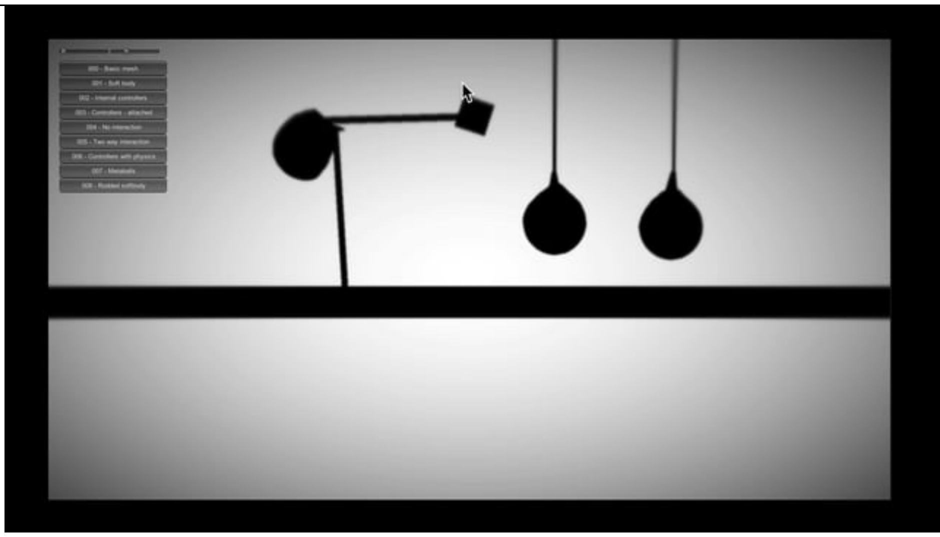
The online Video Comparison Tool[1] assists in the comparison of multiple videos each documenting different approaches to touch based digital puppetry control and movement used across the ShadowEngine project.

Multiple videos can be played at the same time, re-ordered to allow side-by-side comparison, and accessed by keyword coded chapter markers. This allows for close, structured observation of movement. You can hide the chapter markers to make observations without distraction.

The videos included in the tool have been chosen for the following reason. After initial development, I focussed on the expressive and control potential of a range of different techniques: mono-, dual- and multi-touch, the use of simulated physics in spring networks and hierarchies of controller objects, and different *Inverse Kinematic* (IK) solutions - particularly *Forward and Backward Reaching Inverse Kinematics* (FABRIK), where multiple chains of linked object can interact and create complex yet controllable movement. The coded structured observations are then selected for further analysis and critical commentary in *Section 4.1 Results from the New Studies.*

[1] A version is submitted on the accompanying USB key-drive. Internet connection required.

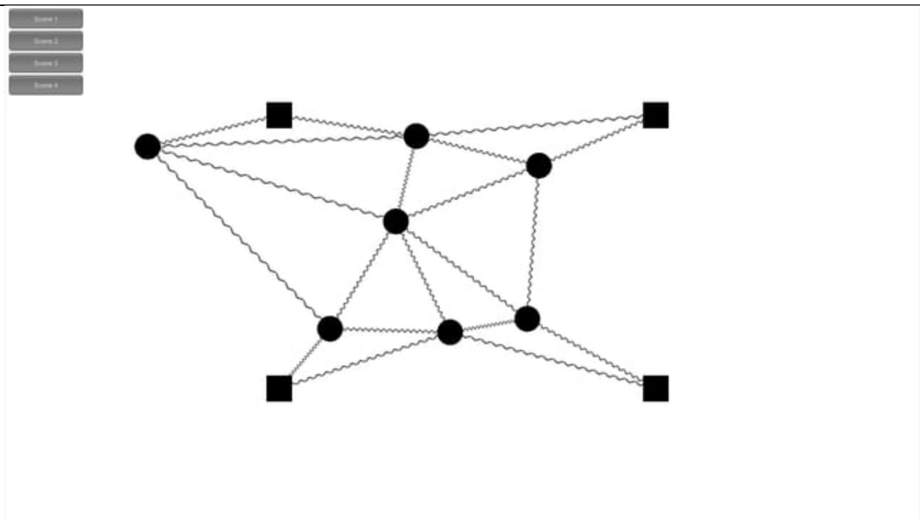
A-3 ANNOTATED VIDEO DOCUMENTATION

Video 1 Foundations - Play with Soft-Body Dynamics	
Link	https://vimeo.com/218777295
File	appendices/a/a1_videos/V01.mp4
Description	Soft-body dynamics, in combination with user interaction and rigid body objects as colliders, provide a rich playground for the digital shadow puppeteer, analogous to material and textural play.
Thumbnail	
Chapter Links and Observation Notes	
(00:08)	Title: Play with interactive soft-body dynamics
(00:16)	000: Basic Mesh
(00:24)	Overview: Floor control
(00:31)	001: Soft Body Interactive Cloth
(00:41)	Breathe
(00:48)	Feature: Internal pressure control
(01:22)	003: Internal controllers. Three sphere colliders - not attached

Video 1 Foundations - Play with Soft-Body Dynamics	
	Observations: Note: predicability of the fail - not random seeded.
(03:10)	003: Controllers - Attached
(03:44)	Greater stability **Note:** circle mouse gesture and a more complex movement in response. Amorphous intriguing shapes Controller momentum Expressive transformations
(04:32)	004: No Interaction: Controllers with Greater Mass The colliders attached to the cloth are set to not have two way interaction. The difference is demonstrated through a comparison with the section 005. Shape transformation. Expressive action / empathic Sense of weight, stretch and squash Mouse control arcs, lines and circles Emergent secondary animation [5m53s] Breath.
(04:49)	Observations: Transformations
(05:35)	Observations: Shapes and contours
(05:53)	Emergent secondary animation
(05:58)	Observations: Breathe
(06:10)	005: Two Way Interaction - Between Cloth and Colliders **Observations:** The cloth exerts a force on the colliders contained within the mesh.

Video 1 Foundations - Play with Soft-Body Dynamics	
	Less dynamism in terms of the shape-changing/ shape making slo-mo - but more 'mimetic' response to mouse gesture [6m35s] Circular gestures encourage the shape to roll Robust and responsive. Retains kinetic energy - damping isn't total.
(07:27)	006: Controllers with Physics The controller objects are moving, but still draggable. **Observations:** Automaton. User can play with the rhythm and tempo. Nice shapes and compositional counterpoint - responsive. Interplay between mouse action and physics behaviours. Interactive shape forming.
(07:39)	Observations: Automaton
(08:10)	Observations: Shapes and counterpoint in movement
(08:36)	007: Metaballs Code based metaballs. **Observations:** Simple attraction and morphing. Simple interaction.
(09:06)	008: Rods and Softbodies **Description:** Cloth 'balloons' attached to moveable control rods and a simple hinged construction with a fabric joint between two element.
(10:10)	Observation: Stable collisions. Creates a sensation and fun when the objects interact-they seem to prod and poke.

Video 1 Foundations - Play with Soft-Body Dynamics	
(10:25)	When the collisions do fail, sometimes there are expressive outcomes.
(11:45)	The internal pressure setting is a fun way to add energy into the objects. Consider mapping this parameter do gaze-duration or another accessible input method and you have an animation system responsive to different kinds of input - that may not rely on the gestural component of moving mice, touching surfaces or moving hands around in front of a camera or sensor. The impossible transformation through inflation does lead to emergent animation. Believable weight and friction from the simulation. Again there are the damping settings do not stop the movement entirely.
(11:56)	Observations: Glitches

Video 2 Foundations: Interactive dynamics in physics engines	
Link	https://vimeo.com/224844059
File	appendices/a/a1_videos/V02.mp4
Description	Box2D, Chipmunk and Springies. A demonstration of interactive dynamics in two popular physics engines. I'm interested in the puppeteering potential and visual qualities of spring networks as a part of how a figure is controlled. The 'Springies' Unity sketches created a germ of an idea: What if the anchors could move and the spring qualities were readily configurable? Could they be configured to provide a rig in which to suspend a multi-jointed, articulated figure?
Thumbnail	
Chapter Links and Observation Notes	
(00:19)	Box2D - Theo Jansen's Walker
(00:34)	Keyboard control. Note momentum
(01:08)	Pulling the creature by the leg often leads to an empathic reaction from viewers.
(01:18)	Motor control. Note the figure still moves while the interaction is happening
(01:40)	Chipmunk Physics - Spring networks
(01:55)	The complex movement flow is engaging. The natural spring and undulations are dynamic and visually rich.

Video 2 Foundations: Interactive dynamics in physics engines	
(02:24)	Springies Unity 3D (2010)
(03:24)	Springies - Additional nodes
(04:21)	Springies - Suspended single pendulum
(04:54)	Springies - Suspended double pendulum
(05:25)	**Observations**: being suspended transforms the behaviour of a free moving pendulum. What if the control points were moveable? What if the spring strengths, damping, etc. were adjustable in real-time?

Video 3 ShadowEngine - First Touch Prototype (screen captures)	
Link	https://vimeo.com/225988222
File	appendices/a/a1_videos/V03.mp4
Description	An introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows mono-touchable figures, being controlled with a single touch from an iPad. The numbered circles represent the touch position, trajectory and finger count. The test figures are from Lotte Reiniger silhouette films and the shadow traditions: Karaghiosis (Greece) and Wayang Kulit (Java). For a view of the animations directly videoed from the iPad screen, show the hand and touches, please see video: https://vimeo.com/218785409

Video 3 ShadowEngine - First Touch Prototype (screen captures)	
Thumbnail	
Chapter Links and Observation Notes	
(00:14)	Shadowengine Mono-Touch direct (screen captures) (titles)
(00:16)	Guidance on touch visualisation
(00:26)	Figure 1: Female figure after Lotte Reiniger
(00:30)	Note: no 'controller' rig. All direct manipulation.
(00:32)	Multi-jointed full physics.
(00:37)	Very much like a rag-doll
(00:41)	Momentum - used to strike poses and move limbs
(00:43)	Some joints hyper-extendable and require constraints?
(00:50)	Using props/furniture to act as rests and pivot points
(01:05)	Working with and against gravity.
(01:07)	Gentle, simple gestures (up and down slide)
(01:14)	Working with orbits of range and reach
(01:21)	Circular gestures create undulation and flow
(01:31)	Weight and reach. Solid placement of feet. Anchors.

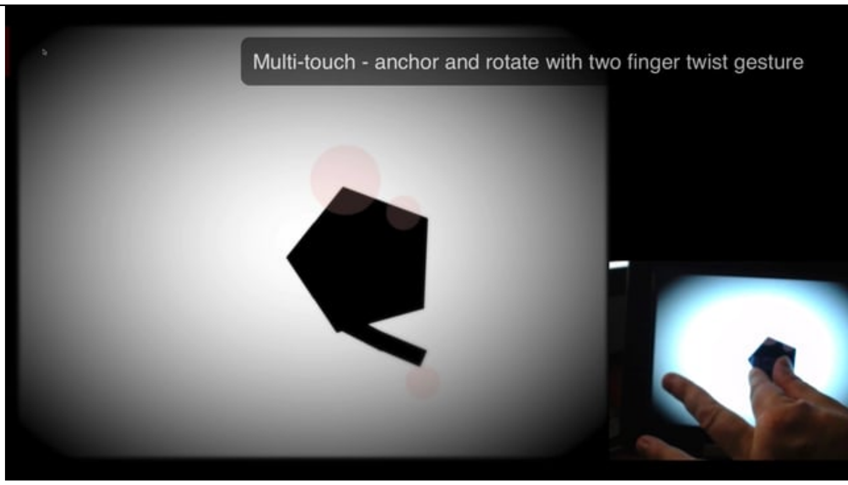
Video 3 ShadowEngine - First Touch Prototype (screen captures)	
(01:36)	Expressive elegance to the silhouette form.
(01:41)	Physics wobble.
(02:00)	Dolly waggling
(02:02)	Springs and joints are robust - no stretch
(02:26)	Figures 2: "Karaghiosis in Albania 1940": After Eugenios Spatharis
(02:35)	Note: no 'controller' rig. All direct manipulation.
(02:39)	Note: set pose. Some waist constraints to allow standing in repose.
(02:41)	Circular movements. Fabulous chain looseness and pace of response
(02:44)	Issue - Some stretching of joints
(02:49)	Sense of 3D Objects (skewed rotation of gun)
(02:55)	Simple single touch leg moves. Work when the figure is constrained in repose.
(03:01)	The tangible figure would have a rod on the gun and just below the shoulder
(03:07)	Interest opacity effects
(03:13)	Hint of 3D freedom of movement
(03:23)	Issue - Joint slide
(03:35)	Simple two-piece figure - possibilities with balance and friction board
(04:25)	Seeking a combination of momentum, direction and friction to do a Y rotation
(04:43)	Rotation! Not completely controllable.
(04:49)	Figure 3: The Magic Horse (Reiniger)
(04:58)	Multi-jointed figure. Elastic joint constraints. Repose = standing.
(05:05)	Poise, attitude. Simple movements.
(05:09)	Lift against the friction = lightness, control

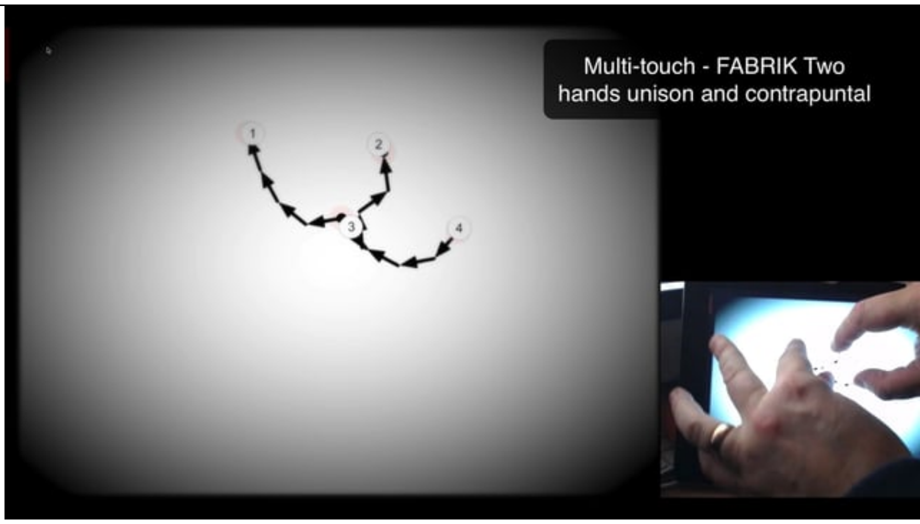
Video 3 ShadowEngine - First Touch Prototype (screen captures)	
(05:15)	Exploring the inner tensions and joint characteristics
(05:22)	Finding movement potential
(05:40)	Movement into poses
(05:43)	Improbable joint constraints / stiffness
(06:39)	Figure 4: Wayang Kulit (Java)
(06:49)	Note: Rod weighting. Acting like anchors
(07:23)	Rods are draggable
(07:42)	Use of Friction Board
(08:06)	Turned off the constraint stopping rotation around the Y (up) axis
(08:17)	Rotation (partial) of the 3D Wayang Kulit
(08:27)	Effective rotation. Requires perspective and Camera adjustments
(08:38)	Finding the most effective rotation gesture
(08:43)	Extremity as rotation grab point
(08:46)	Arm used to pull to rotate figure (emulates analogue figure)
(09:24)	Leading movement with the arms is interesting. Compare with controller system with parented controllers
(09:28)	Consider: constraints vs degrees of freedom

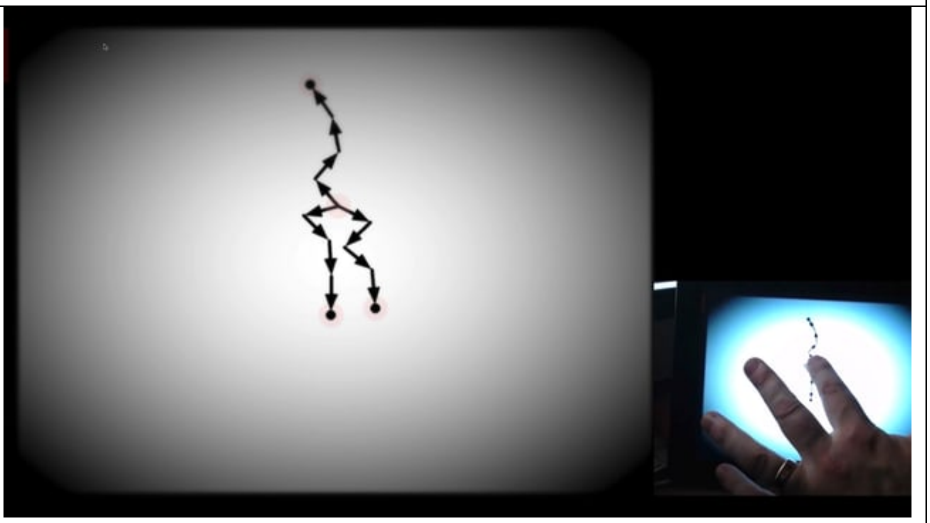
Video 4 ShadowEngine - First Touch Prototype (video)	
Link	https://vimeo.com/218785409
File	appendices/a/a1_videos/V04.mp4
Description	Here is an introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows the iPad, mono-touch figures and the modelling process. The test figures are two silhouettes from Lotte Reiniger shadow films and the shadow traditions: Karaghiosis (Greece) and Wayang Kulit (Java). The iPad handling is videoed live and the hand, at times, conceals the animation. The accompanying video 'ShadowEngine: First Touch Prototype (screen captures)' records the animations directly. The hand gets in the way at times and obscures the view. The conductive stylus is an interesting alternative and has a similarity to removable rods used as controllers in analogue shadow theatre. For a view of the animations directly screen-captured from the iPad without the hand, please see the following video: https://vimeo.com/225988222 Please turn on the closed captions for additional (written) commentary.
Thumbnail	
Chapter Links and Observation Notes	

Video 4 ShadowEngine - First Touch Prototype (video)	
(00:21)	First-generation iPad Unity iPhone 1.7.0. May, 2010
(00:46)	Female figure After Lotte Reiniger
(00:58)	The joint set-up was a test. Stiff in places. Loose and unrestricted in others. The front arm has no damping.
(01:34)	The setup of the character: working from image, to 3D model, then to Unity rigging is very time consuming.
(01:53)	Karaghiosis in Albania 1940"" After Eugenios Spatharis
(02:21)	**Observations**: The drag is unresponsive. Though the touch feels laggy, the articulated figure is quite lively. Two reasons: the weight and scale of the figure is off or the settings of the dragging 'spring' need strengthening. Target points are hard to hit. Currently all the mesh objects are set to be a target for a touch. When the point is thin or self-occluded in some way, the touch sometimes fails to respond. Idea: externalise the targets, have an option to make them visible. This is implemented in future demos. Note the overlapping figures: Good: no physics clashes. The shader needs to have the equivalent effect of a blending mode in Photoshop set to 'darken'.
(02:32)	Note the overlapping figures: Good: no physics clashes. A shader should 'darken' the intersection.
(03:14)	Process: a quick view of the Karaghiosis modelling setup.
(05:05)	The figures are 3D geometry and have depth and volume.
(05:30)	Note: the pivot points and the model hierarchy of parts.
(06:57)	Nice landing. The tension and initial pose is in balance. It is a bit stiff. I'd add a joint, with narrow angular limits midpoint along the back.

Video 4 ShadowEngine - First Touch Prototype (video)	
(07:40)	The multi-jointed quadruped is hard to control with a single touch point.
(08:00)	Process: a quick view of the horse modelling setup in Modo.
(08:16)	An atlas of the figure, with alpha channels can be rendered directly from Modo.
(09:07)	Wayang Kulit (Java)
(09:17)	The rotation here is a quirk, albeit a satisfying one. Floor friction, the rigid-body axis constraints settings and a slight downward swipe gesture initiates a rotation.
(09:41)	Dragging a rod/arm also allows the figure to rotate.
(09:57)	Surprising stable and reliable rotation: an advantage of a 3D model.

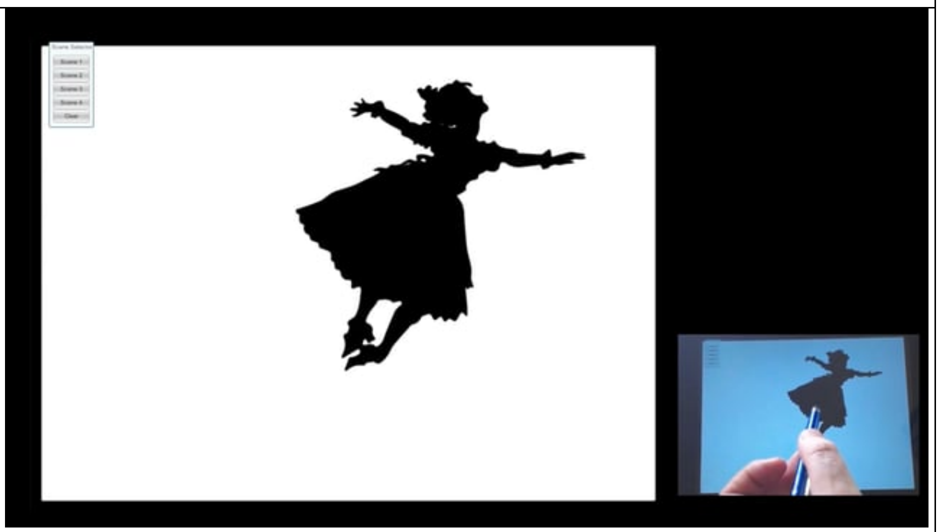
Video 5 Movement and control - Prototype for rotation	
Link	https://vimeo.com/247687400
File	appendices/a/a1_videos/V05.mp4
Description	Movement and control - Prototype for multi-touch, physics & object rotation (y-axis)
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Movement and Control - Prototype for rotation (Titles)
(00:18)	Expressivity: movement and control Prototype for multi-touch, physics and whole object rotation (y-axis)
(00:25)	Drag the main body to move independently from controllers
(00:30)	Object physics reactions on controller drag
(00:37)	Mostly stable. Some part separation.
(00:44)	Multi-touch - anchor and rotate with two finger twist gesture
(00:51)	Multi-touch - anchor and rotate with two hands two finger twist gesture
(01:23)	Use of friction board
(01:44)	Two handed, two-finger twist to spin gesture
(01:58)	Double click to rotate: physics stable. Rotation is working.

Video 6 Movement and control - FABRIK test objects (1)	
Link	https://vimeo.com/247687384
File	appendices/a/a1_videos/V06.mp4
Description	Movement and control - FABRIK test objects (1)
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	FABRIK test objects (1)
(00:18)	Expressivity: movement and control FABRIK Demo objects (1)
(00:22)	FABRIK Explanation
(00:33)	FABRIK Example 1: Root at base
(00:58)	Multi-touch - FABRIK Two hands unison and contrapuntal
(01:10)	FABRIK - Mimetic movement and poses
(01:15)	FABRIK - Reaching for a goal

Video 7 Movement and control - FABRIK Demo objects (2)	
Link	https://vimeo.com/247687477
File	appendices/a/a1_videos/V07.mp4
Description	Movement and control - FABRIK Demo objects (2)
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	FABRIK Demo objects (2) (Titles)
(00:18)	Expressivity: movement and control FABRIK Demo objects (2)
(00:39)	FABRIK Example 2: Root at centre
(00:44)	The bottom controller acts as a positional constraint
(00:49)	Touch movement = dynamics of a bounce
(01:07)	FABRIK - Multi-touch spiral gestures (one hand)
(01:19)	Gesture failure - twist to rotate
(01:19)	A sense of attraction to the end effectors (goals)
(01:38)	A sense of a figure jumping - the use of positional constraints

Video 8 Monotouch - First iPad Prototype - Lotte Reiniger Figure	
Link	https://vimeo.com/248204404
File	appendices/a/a1_videos/V08.mp4
Description	An introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows mono-touchable figures, being controlled with a single touch from an iPad. The numbered circles represent the touch position, trajectory and finger count. This figure is based on a female figure by Lotte Reiniger. It is deliberately ambitious with so many points of articulation. The joint set-up was a test. It is stiff in places. Loose and unrestricted in others. The front arm has no damping. [1m58s] The setup of the character: working from image, to 3D model, then to Unity rigging is very time consuming. Maybe with anchored parts and constraints, such a figure could survive live manipulation. The experiments with 'gravity' and multi-touch in *V09 Multi-touch and effects - Reiniger's Female Figure*, show promise. The repose position designs affordances of certain movement into the figure. For a view of the animations directly videoed from the iPad screen, show the hand, stylus and touches, please see the video: https://vimeo.com/218785409
Thumbnail	
Chapter Links and Observation Notes	

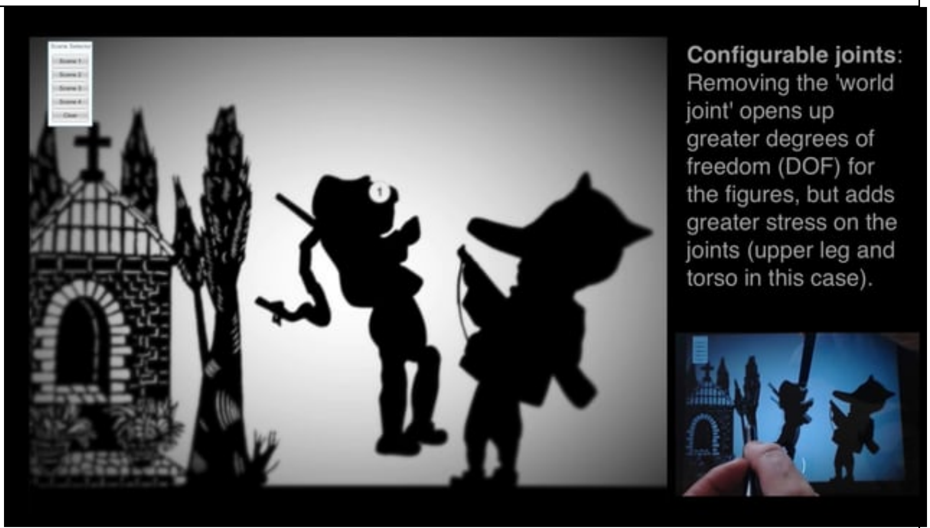
Video 8 Monotouch - First iPad Prototype - Lotte Reiniger Figure	
(00:14)	ShadowEngine Mono-Touch Direct screen captures
(00:16)	Guidance on touch visualisation
(00:25)	Figure 1: Female figure after Lotte Reiniger
(00:30)	Note: no 'controller' rig. All direct manipulation.
(00:32)	Multi-jointed full physics.
(00:37)	Very much like a rag-doll
(00:41)	Momentum - used to strike poses and move limbs
(00:43)	Some joints hyper-extendable and require constraints?
(00:50)	Using props/furniture to act as rests and pivot points
(01:05)	Working with and against gravity.
(01:07)	Gentle simple gestures (up and down slide)
(01:14)	Working with orbits of range and reach
(01:21)	Circular gestures create undulation and flow
(01:31)	Weight and reach. Solid placement of feet. Anchors.
(01:36)	Expressive elegance to the silhouette form.
(01:41)	Physics wobble.
(01:58)	The joint set-up was a test. It is stiff in places. Loose and unrestricted in others. The front arm has no damping. [1m58s]
(02:00)	Dolly waggling
(02:02)	Springs and joints are robust - no stretch

Video 9 Multi-touch and effects - Reiniger's Female Figure. First iPad prototype (direct screen captures)	
Link	https://vimeo.com/248320696
File	appendices/a/a1_videos/V09.mp4
Description	ShadowEngine: Multi-touch and effects. First iPad prototype (iPad captures)
Thumbnail	
Chapter Links and Observation Notes	
(00:15)	Dates and software information
(00:44)	Note the use of two small stylus and finger touches
(01:10)	Multi-touch assists directed control. But the figure's repose tensions and settings are crucial
(01:21)	3D physics glitching - tensions
(01:28)	Gestures: hand / touch swop over works nicely
(01:32)	Gravity switch: activated. The direction of gravity is switched to -Z. Effectively, the figure is effectively resting on a rostrum. Some risidual springiness moves the characters.
(01:43)	Flow and pose setting
(01:58)	Different physics model: the jointed resistance and secondary movement is interesting

Video 9 Multi-touch and effects - Reiniger's Female Figure. First iPad prototype (direct screen captures)	
(02:06)	Multi-touch leads to spring physics / joint stretching
(02:24)	Dress physics / constraint jitters. But the silhouette line tolerates a slight distortion.
(02:53)	Move the foot, lovely hand / arm auto-movement.
(03:24)	There is a configurable joint (with spring) that is join the body to 'the World'. It creates some of the 'automatic' movement.
(03:41)	Gestures: trying big, curved stylus paths.

Video 10 Monotouch-First iPad Prototype - Karaghiosis	
Link	https://vimeo.com/248204346
File	appendices/a/a1_videos/V10.mp4
Description	An introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows mono-touchable figures, being controlled with a single touch from an iPad. The numbered circles represent the touch position, trajectory and finger count. This video features Karaghiosis and friend from Greece. For a view of the animations directly videoed from the iPad screen, show the hand and touches, please see video: https://vimeo.com/218785409
Thumbnail	
Chapter Links and Observation Notes	
(00:16)	Guidance on touch visualisation
(00:27)	Figures 2: Karaghiosis and friend
(00:37)	Note: no 'controller' rig. All direct manipulation.
(00:41)	Note: set pose. Some waist constraints to allow standing in repose. Circular movements. Fabulous chain looseness and pace of response
(00:46)	Issue - Some stretching of joints

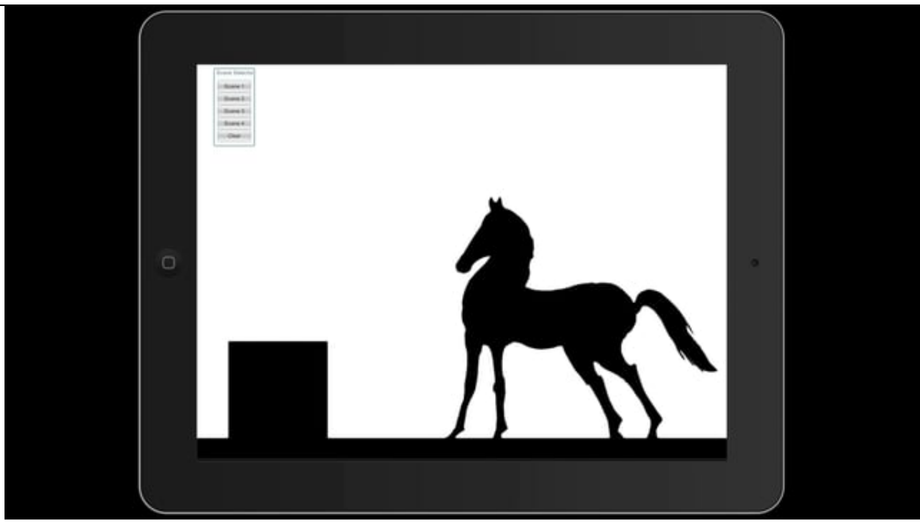
Video 10 Monotouch-First iPad Prototype - Karaghiosis	
(00:51)	Sense of 3D Objects (skewed rotation of gun)
(00:57)	Simple single touch leg moves. Work when the figure is constrained in repose.
(01:03)	The tangible figure would have a rod on the gun and just below the shoulder
(01:08)	Interest opacity effects
(01:15)	Hint of 3D freedom of movement
(01:24)	Issue - Joint slide
(01:37)	Simple 2 piece figure - possibilities with balance and friction board
(02:27)	Seeking a combination of momentum, direction and friction to do a Y rotation
(02:45)	Rotation! Not completely controllable.

Video 11 Multi-touch and Effects-Karaghiosis. First iPad prototype (direct screen captures)	
Link	https://vimeo.com/248357608
File	appendices/a/a1_videos/V11.mp4
Description	Multi-touch and Effects: Karaghiosis. First iPad prototype (direct screen captures) Multi-touch iPad prototype - Karaghiosis
Thumbnail	
Chapter Links and Observation Notes	
(00:15)	Dates and software information
(00:38)	Configurable joints hold each character in their repose position
(00:56)	3D rotation is enabled by unlocking Y rotation locks on both body parts and angular constraints in the 'world joint'.
(01:01)	The camera is in orthographic mode: flattening any depth information. So there are no accurate perspective or skewing distortions.
(01:06)	Multi-touch is working! It took a long while to get right. Simple two jointed characters bend and move in a predictable way.
(01:16)	Attempting to find a gesture for a rotation. The figure may be still locked or the dragging object might be planar to the figure...

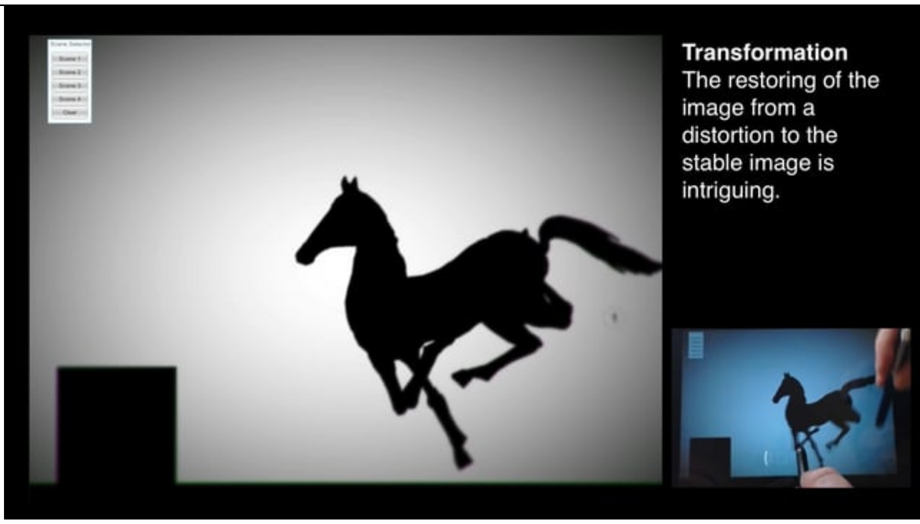
Video 11 Multi-touch and Effects-Karaghiosis. First iPad prototype (direct screen captures)	
(01:29)	The long multi-part arm is typical of the Greek Karaghiosis protagonist (with one exception). It is usually rodded at the hand (here a gun) with a second hinged rod below the shoulder, on the edge.
(01:34)	Multi-touch working nicely to direct separate elements: providing a variety of interactions between each touch: compressions, extensions, pivots, rotations and more.
(01:44)	Multi-touch: combinations of the figures articulations, touch and momentum and the friction board (floor) to create compound, expressive movements.
(01:49)	Multi-touch: one major reason for requiring multi-touch! The control of multiple characters at once.
(02:02)	Silhouette mode: added to the first prototype. It reinforces something powerful about the shadow. The morphology is somehow flexible, plastic and transformed...
(02:28)	Physics and colliders: the figures are set to 'self-intersect' and intersect with each other. Some objects: the floor and props are set to collide with the virtual objects.
(02:37)	Greyscale mode: added to the first prototype. It tints the material to wash out colour, simulating the translucency of material shadow figures against screens.
(02:45)	Movement qualities: Note the reliability of the gesture and pick-up. Practising with the system requires aspects of the physics-based system to act in a predictable way.
(02:57)	Configurable joints: Here I disable the joints that help the figures stand unaided. The angular constraints and forces at work in the figures mean they still stand.
(03:04)	Configurable joints: Removing the 'world joint' opens up greater degrees of freedom (DOF) for the figures but adds greater stress on the joints (upper leg and torso in this case).
(03:26)	Fixing separating parts: There are expressive qualities to the glitch. I have a range of responses to this: mimetic, e.g. draw links between joints that

Video 11 Multi-touch and Effects-Karaghiosis. First iPad prototype (direct screen captures)	
	appear elastic or magic.
(03:34)	Without the anchoring world, joints and the art of not stretching the figure is practised, the range and flow of movement are more open and has a greater range of tempo.
(03:56)	All angular constraints on Y axis off. At last, we discover the most effective rotation/flip of a figure (although perspective is flattened).
(04:30)	Rotation: The figure is a bit unpredictable. It may need virtual 'weight' at the feet and stronger 'spring' joints holding the parts together.
(04:45)	Vignette Effect
(04:54)	Colour then Greyscale Effect
(04:58)	Monochrome Effect
(05:04)	Configurable joints: Removed the 'world joint' holding Karaghiosis on a virtual piece of soft elastic and all Y rotational limits.
(05:28)	Gravity switch: activated. The direction of gravity is switched to -Z. Effectively, the figures are resting on a surface, with a level of friction.
(05:46)	Positional control and Poses: There is some drift happening due to spring settings in the joints. It is a very different feel.
(06:31)	Gesture: Two finger twist on the multi-jointed chain has the correct response (local rotation/spin of connected elements).
(06:40)	Gravity on!
(06:43)	Touch control: Sensitive. Caught the unconstrained figure.
(06:52)	Multi-touch control: Predictable rotate.
(06:54)	Physics glitch: Stretch and shake.
(07:10)	Physics glitch: Stretch and split.
(07:14)	Physics glitch: Breathe and bounce.

Video 11 Multi-touch and Effects-Karaghiosis. First iPad prototype (direct screen captures)	
(07:18)	Gravity off. Or redirected.
(07:29)	Physics response: Notice the predictable 'recoil' through the system that drags the arm and gun back.
(07:34)	Constraints off
(08:38)	Physics response: Notice the after-movement due to angular limits on hinge joints returning the parts to their resting position. Distracting?
(08:42)	Gravity on.

Video 12 Monotouch-First iPad Prototype - The Magic Horse (Reiniger)	
Link	https://vimeo.com/248204301
File	appendices/a/a1_videos/V12.mp4
Description	An introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows mono-touchable figures, being controlled with a single touch from an iPad. The numbered circles represent the touch position, trajectory and finger count. This video features the Magic Horse after Lotte Reiniger. For a view of the animations directly videoed from the iPad screen, show the hand and touches, please see video: https://vimeo.com/218785409
Thumbnail	
Chapter Links and Observation Notes	
(00:14)	ShadowEngine Mono-Touch Direct screen captures
(00:16)	Guidance on touch visualisation
(00:25)	Figure: The Magic Horse (Reiniger)
(00:35)	Multi-jointed figure. Elastic joint constraints. Repose = standing.
(00:42)	Poise, attitude. Simple movements.

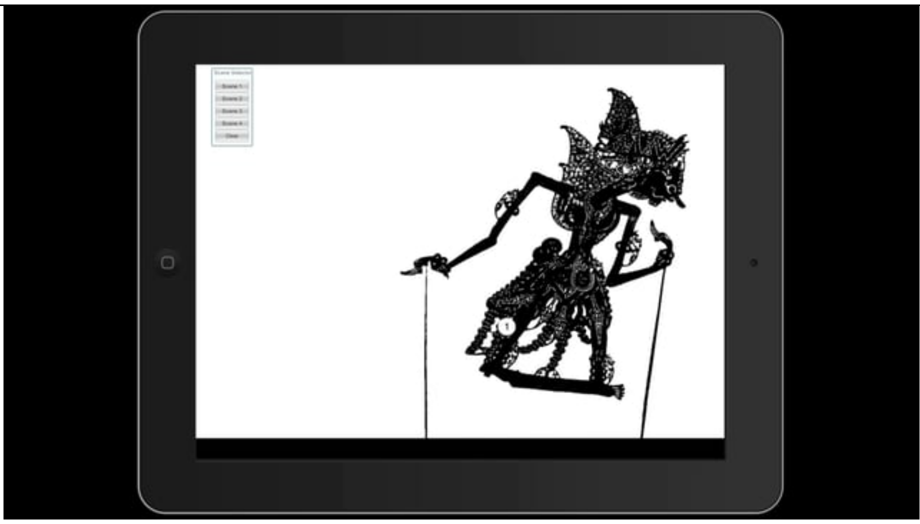
Video 12 Monotouch-First iPad Prototype - The Magic Horse (Reiniger)	
(00:46)	Lift against the friction = lightness, control
(00:52)	Exploring the inner tensions and joint characteristics
(01:00)	Finding movement potential
(01:17)	Movement into poses
(01:20)	Improbable joint constraints/stiffness

Video 13 Multi-touch and Effects - Reiniger's Horse. First iPad prototype (direct screen captures)	
Link	https://vimeo.com/248397745
File	appendices/a/a1_videos/V13.mp4
Description	Multi-touch and Effects: Reiniger's Horse. First iPad prototype (direct screen captures)
Thumbnail	
Chapter Links and Observation Notes	
(00:15)	Dates and software information
(00:35)	Visual effects: vignetting, blur, anti-aliasing.
(00:40)	Mono-touch to multi-touch - or in most of these videos dual-touch.

Video 13 Multi-touch and Effects - Reiniger's Horse. First iPad prototype (direct screen captures)	
(01:51)	Gravity switch: activated. The direction of gravity is switched to -Z. Effectively, the figures are resting on a surface, with a level of friction. An unplanned mode of interaction.
(02:01)	Horse manipulation after William Kentridge's 'Making a Horse'
(02:19)	The rotation angle constraints are too strict to allow free posing of the horse. It resists and re-positions elements.
(02:46)	Transformation: The restoring of the image from a distortion to the stable image is intriguing.
(03:20)	Non-mimetic: Comic, grotesque distortions. An uncomfortable deforming of the expected shape.
(03:37)	Play: Quite rough play: Testing joints, physics integrity while finding shapes and moves.
(03:46)	Mimetic movements: do begin to emerge. A similar process to finding the 'kinetic' personality of objects.
(03:55)	Mimetic and non-mimetic movements: traces of ideas and intentionality as the object play progresses.
(04:05)	Tracking glitch: This segment was made when the touch tracker required a fix. It is glitchy but makes an interesting movement, with a different style of interaction.
(04:40)	Gravity switch: activated.
(05:06)	Touch space: screen space mapping should not be 1:1. The touch area should give access to off-screen space. This is explored in the second prototype.
(05:27)	Gravity switch: toggled.
(05:58)	Movement play: Exploring the tilt and balance point. The styluses turn into a flexible virtual paddle.
(06:20)	Unpredicted interaction: Due to the touch tracking glitch, the second touch adds a competing spring joint that modulates the attraction of the first touch.

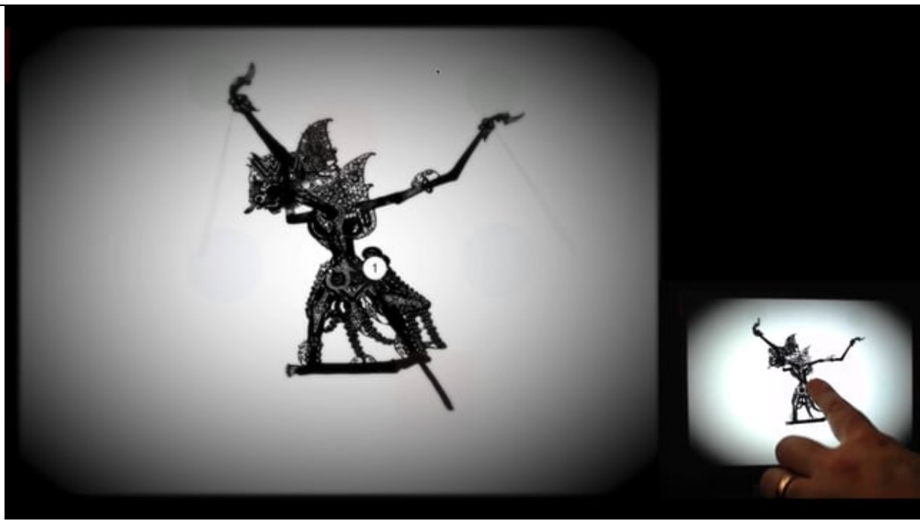
Video 14 Monotouch-First iPad Prototype - Wayang Kulit	
Link	https://vimeo.com/248202203
File	appendices/a/a1_videos/V14.mp4
Description	An introduction to the first ShadowEngine prototype. Made using a first-generation iPad, Unity iPhone 1.7.0 (May 2010). The video shows mono-touchable figures, being controlled with a single touch from an iPad. The numbered circles represent the touch position, trajectory and finger count. This video features the Wayang Kulit figure from Java. For a view of the animations directly videoed from the iPad screen, show the hand and touches, please see video: https://vimeo.com/218785409
Thumbnail	
Chapter Links and Observation Notes	
(00:14)	ShadowEngine Mono-Touch Direct screen captures
(00:16)	Guidance on touch visualisation
(00:25)	Figure: Wayang Kulit (Java)
(00:35)	Note: Rod weighting. Acting like anchors
(01:10)	Rods are draggable

Video 14 Monotouch-First iPad Prototype - Wayang Kulit	
(01:29)	Use of Friction Board
(01:52)	Turned off the constraint stopping rotation around the Y (up) axis
(02:03)	Rotation (partial) of the 3D Wayang Kulit
(02:13)	Effective rotation. Requires perspective and Camera adjustments
(02:24)	Finding the most effective rotation gesture
(02:30)	Extremity as rotation grab point
(02:33)	Arm used to pull to rotate figure (emulates analogue figure)
(03:11)	Leading movement with the arms is interesting. Compare with controller system with parented controllers
(03:15)	Consider: constraints vs degrees of freedom

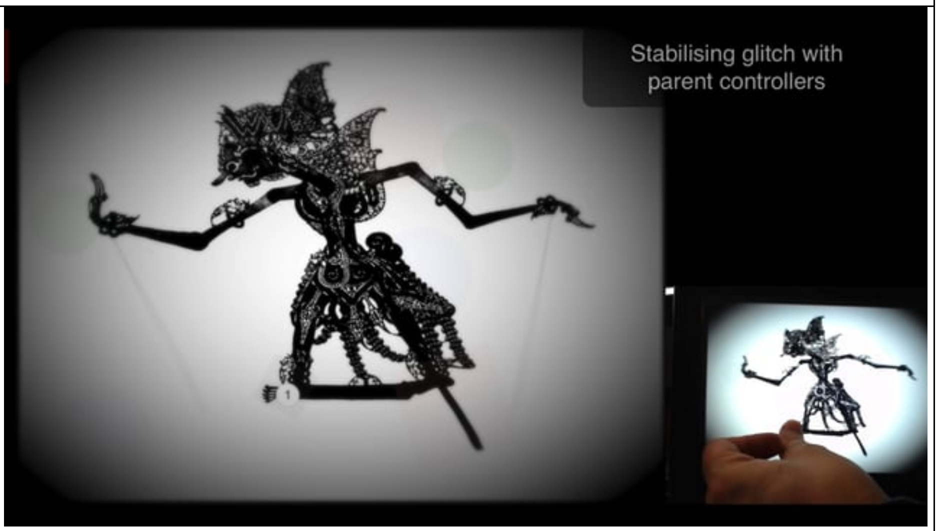
Video 15 Multi-touch and Effects - Wayang Kulit First iPad prototype	
Link	https://vimeo.com/248387967
File	appendices/a/a1_videos/V15.mp4
Description	Multi-touch and Effects: Wayang Kulit First iPad prototype (direct screen captures)
Thumbnail	

Video 15 Multi-touch and Effects - Wayang Kulit First iPad prototype	
Chapter Links and Observation Notes	
(00:15)	Dates and software information
(00:31)	Visual effects: vignetting, blur, anti-aliasing.
(00:37)	Multi-touch: dynamic, snappy. Some physics stress on upper arm joints
(00:46)	Gesture: attempts at two touch twist to rotate. The rotation limits on the figure prevent this.
(00:57)	Multi-touch: using base shape and friction board to create subtle movements.
(01:13)	Constraints: There are constraints on the rods, minimising the amount of rotation. This locks the rods to an off-screen origin, but limits freedom of movement.
(01:32)	Physics: Spectacular fail, but the figure robustly re-assembles itself.
(01:49)	Constraints: Trying small motions, but the rod constraints dampen any response. Turn constraints off.
(02:10)	Rods: The rods are an important sign of control. Here the sign lacks coherence. In analogue control, the rod is a vehicle for an impulse.
(02:19)	Rods: The original image pictured the central core rod running from the tip of the head to below the current base. The 3D model had issues with unwanted collisions, so it was removed. Unfortunate, regrettable and therefore incomplete.
(02:40)	Rods: Attempt to use a rod movement as an impulse for a rotation.
(03:14)	Rods: Using the styluses to touch the rods are a tangible meta-controller.
(03:23)	Rotations are controllable but further figure configuration tweaks are necessary.
(03:44)	Touch Control Technique: The passing of an object between controllers is a very pleasing discovery. Fingers do not feel as precise.
(04:03)	Visual effect: I created a toggle between the orthographic and perspective cameras. This enables depth of field and aims to create the shadow defocusing effect seen on material screens when the objects tilt.

Video 15 Multi-touch and Effects - Wayang Kulit First iPad prototype	
(04:11)	Visual effect: The depth of field effect focuses objects in one range of distance from the camera and defocuses everything else.
(04:18)	Freeze-frame: The perspective camera creates some foreshortening that we would expect. Except: it is inverted. Small edge = closer to screen = in focus. But it is not.
(04:25)	Freeze-frame: The perspective camera creates some foreshortening that we would expect. Small edge = closer to screen = in focus. Except: it is inverted.
(04:38)	A Depth of Field (DOF) effect: A better example of the depth of field effect in a still. For shadows on a material screen, the object casting the larger shadow should be further away from the screen and blurred. It is a perspective illusion that requires movement cues.
(05:35)	Perspective mode: In perspective camera mode you can 'see' or infer the receding plane as the puppet lands on the floor.
(05:51)	Orthographic mode: Uniformly flattens perspective - it's a kind of parallel projection.
(06:13)	Gravity switch: activated. The direction of gravity is switched to -Z. Effectively, the figures are resting on a surface, with a level of friction.
(06:30)	Precise positioning: But lacking dynamism.
(06:51)	Perspective mode: The gravity switched or what I call 'ant farm mode' with a perspective camera.
(07:32)	Wonderful mini chaos
(07:41)	Orthographic mode
(07:54)	Rotation: Attempting to rotate.

Video 16 Movement and control - Spring Networks: Wayang Kulit	
Link	https://vimeo.com/247688462
File	appendices/a/a1_videos/V16.mp4
Description	Movement and control - Spring Networks: Wayang Kulit
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Spring Networks: Wayang Kulit (titles)
(00:27)	Mono-touch and Controller Hierarchies
(00:36)	Patterns of Touch Movement
(00:47)	Multi-touch
(00:58)	Moving the parent in controller hierarchy
(01:02)	Moving the Root controller - Arms
(01:37)	Controller - Glitch and Tension
(01:47)	Solver flick (Spring) - Glitch
(01:56)	Movement decay / damping
(02:05)	Parent movement and tension
(02:10)	What's missing? Figure rotation

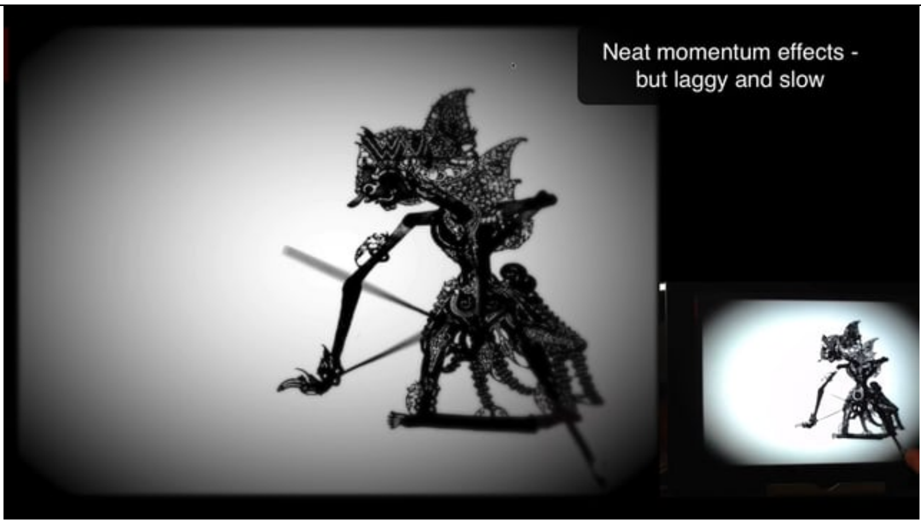
Video 16 Movement and control - Spring Networks: Wayang Kulit	
(02:14)	Controllers as targets and reach
(02:20)	Precision and Accidents
(02:25)	Imprecision and Touch failure
(02:30)	Setting and relieving tension
(02:40)	Multi-touch accuracy / contact errors
(02:49)	Contra-movements
(02:56)	Two finger anchor 3rd finger rotate
(03:00)	Two finger rotate / spin (pairs)

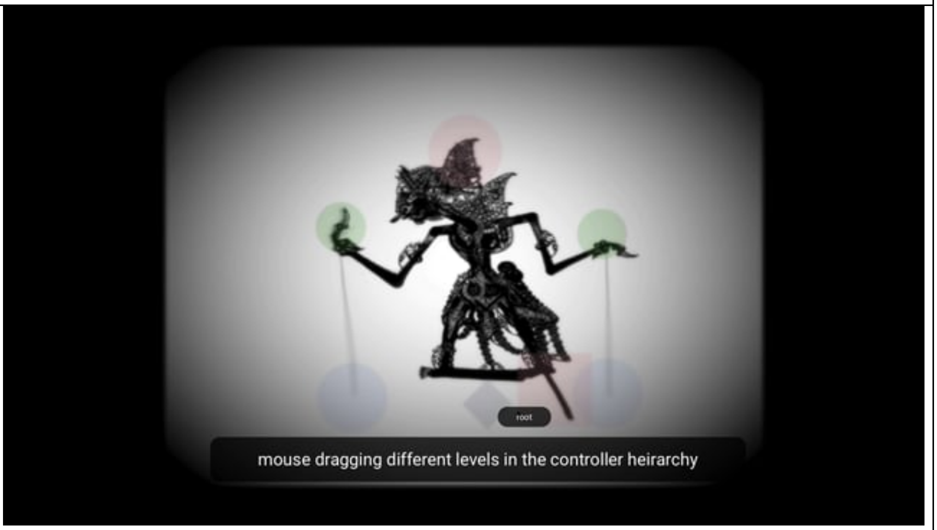
Video 17 Movement and control - Spring networks - flatter hierarchy: Wayang Kulit	
Link	https://vimeo.com/247689659
File	appendices/a/a1_videos/V17.mp4
Description	Spring networks - flatter hierarchy: Wayang Kulit
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Spring networks - flatter hierarchy: Wayang Kulit (TItles)
(00:18)	Expressivity: movement and control Spring networks - flatter hierarchy: Wayang Kulit
(00:29)	Unity 3D physics prefers flatter non-hierarchical elements
(00:32)	Smooth secondary movements and damping
(00:37)	Physics on children when parent controller moves
(00:39)	Gesture - pinch on root controller to scale
(00:48)	Failing touches
(01:21)	Tension glitch
(01:29)	Leaning, anchoring, limb rotation
(01:36)	Rhythmic physics glitches

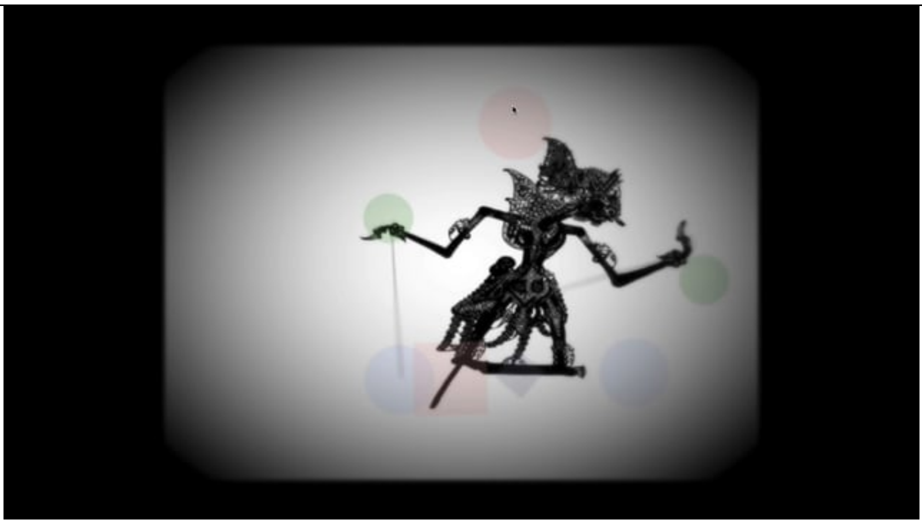
Video 17 Movement and control - Spring networks - flatter hierarchy: Wayang Kulit	
(01:50)	Using friction-board as control and stabiliser
(02:04)	Stabilising glitch with parent controllers
(02:20)	Multi-touch twist gestures
(02:31)	Circular movement
(02:37)	Attempted twist
(02:51)	Unpredictable scaling
(03:06)	Reset after uncontrollable scaling
(03:21)	Single touch
(03:41)	Multi-touch - twist gestures
(04:01)	Touch and mouse control - combination

Video 18 Movement and control - FABRIK - Wayang Kulit	
Link	https://vimeo.com/247688813
File	appendices/a/a1_videos/V18.mp4
Description	FABRIK - Wayang Kulit
Thumbnail	

Video 18 Movement and control - FABRIK - Wayang Kulit	
Chapter Links and Observation Notes	
(00:00)	FABRIK - Wayang Kulit (Titles)
(00:25)	A re-written UI
(00:32)	Mono-touch - stability no gravity simulation
(00:50)	'Gimbal lock' - flick
(00:53)	Base controller
(01:01)	Arm controller - notice root controller is anchor/pivot
(01:11)	Subtle, slow tempo
(01:31)	Undulation (wave movement) using the flick
(01:37)	Multi-touch - FABRIK
(02:00)	Issue: touch space to screen space mapping
(02:25)	Spring Network - Flatter Hierarchy

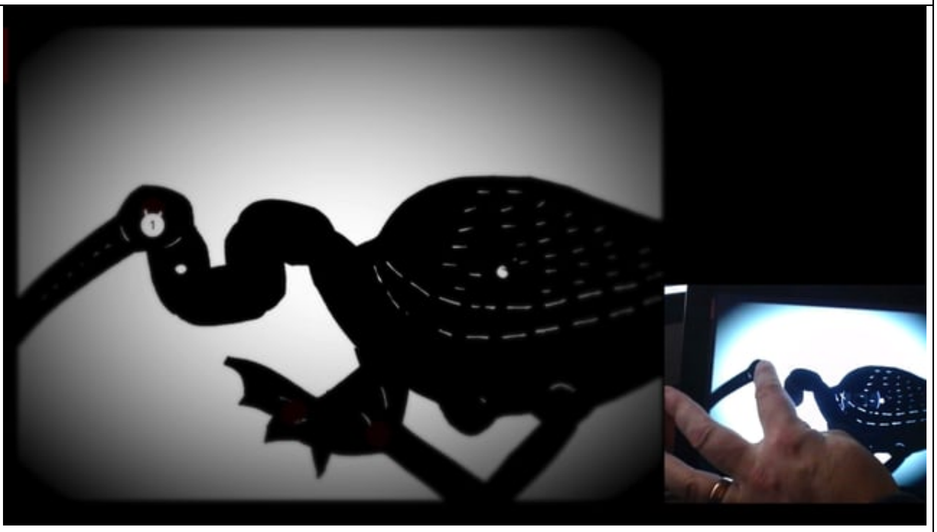
Video 19 Movement and control - Direct control - Wayang Kulit (fail)	
Link	https://vimeo.com/247689420
File	appendices/a/a1_videos/V19.mp4
Description	Direct control - Wayang Kulit (fail)
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Direct control - Wayang Kulit (fail)
(00:37)	Full Physics
(00:41)	Weight of parts and simulation is off (slow)
(00:46)	Neat momentum effects - but laggy and slow
(00:55)	Rods - conspicuous and clearly not leading the movement
(00:57)	Scaling - slightly glitchy
(00:59)	Mass glitch - joint separation
(01:04)	Smaller scale - precision and pace of movement
(01:13)	Attempted twist to rotate gesture
(01:17)	Collision issues - need more colliders

Video 20 Movement and control - Mouse Control - Scroll Wheel Rotation	
Link	https://vimeo.com/232825643
File	appendices/a/a1_videos/V20.mp4
Description	Demonstration of single point control and the use of the scroll wheel to rotate specific controllers.
Thumbnail	
Chapter Links and Observation Notes	
(00:09)	Design for Movement: Mouse Control - Scroll Wheel Rotation (Titles)
(00:25)	Mouse Dragging Controllers
(00:35)	Mouse Scrolling on Bottom Controller to Rotate Controller Set
(00:43)	2D Flip Rotation
(00:55)	Mouse scrolling on Top Controller to Rotate Controller Set

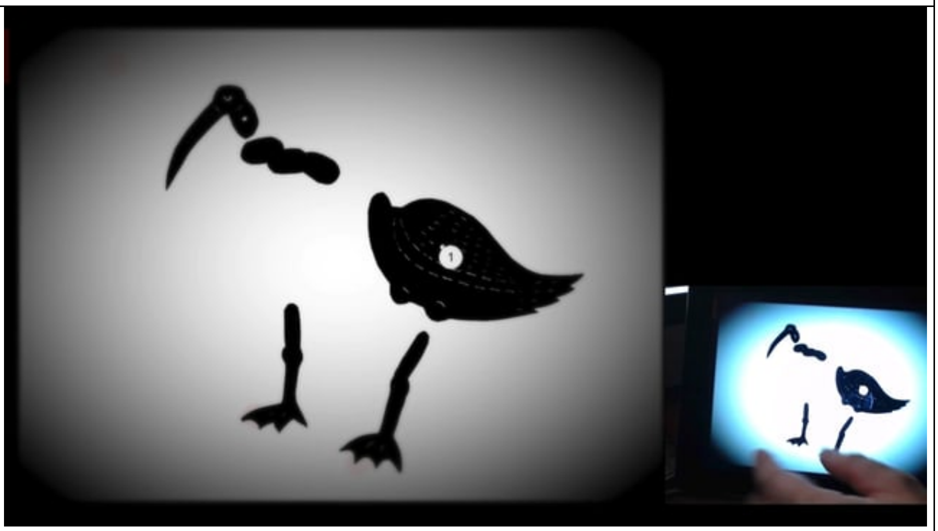
Video 21 Mouse control - Scroll wheel rotation	
Link	https://vimeo.com/190084637
File	appendices/a/a1_videos/V21.mp4
Description	Demonstration of the use of the mouse scroll wheel to rotate specific controllers. The figure has been set up for multi-touch and the mono-touch of single point control, like a mouse.
Thumbnail	
Chapter Links and Observation Notes	
(00:34)	Mouse scrolling - bottom controller. Stable physics response and dynamic arm movement.
(00:39)	Flip rotation - double tapping/clicking body.
(00:50)	Mouse scrolling - top controller. Dynamic arm movement

Video 22 Movement and control - Spring network - Karagöz bird figure	
Link	https://vimeo.com/247689825
File	appendices/a/a1_videos/V22.mp4
Description	Spring network - Karagöz bird figure
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Spring network - Karagöz bird figure (Titles)
(00:18)	Expressivity: movement and control Spring network - Karagöz bird figure (1)
(00:29)	Hierarchy of controllers
(00:47)	Multi-touch twist gesture = tilt controller
(00:56)	Double-tap (or click) = eye blink
(01:07)	Twist to rotate on a single controller
(01:15)	Controllers positioned to create tilt per puppet part
(01:24)	Stretch against anchors (stable)
(01:30)	Interplay of joint, control forces and collisions create articulations
(01:36)	Single and parented controllers

Video 22 Movement and control - Spring network - Karagöz bird figure	
(01:52)	Pinch to scale controller (stable)
(02:06)	Emerging pattern - using single touches to pose
(02:13)	UI - Switch to monochrome
(02:31)	Double-tap / click to blink eye
(02:35)	Spring Network - Flatter Hierarchy
(02:43)	Attempt to control scaling
(02:47)	Physics glitch - foot stuck on friction board
(03:15)	Pose setting and mimetic movement
(03:35)	Expressive framing
(03:42)	UI - Cinematic effects

Video 23 Movement and control - FABRIK - Karagöz bird figure	
Link	https://vimeo.com/247689499
File	appendices/a/a1_videos/V23.mp4
Description	FABRIK - Karagöz bird figure
Thumbnail	

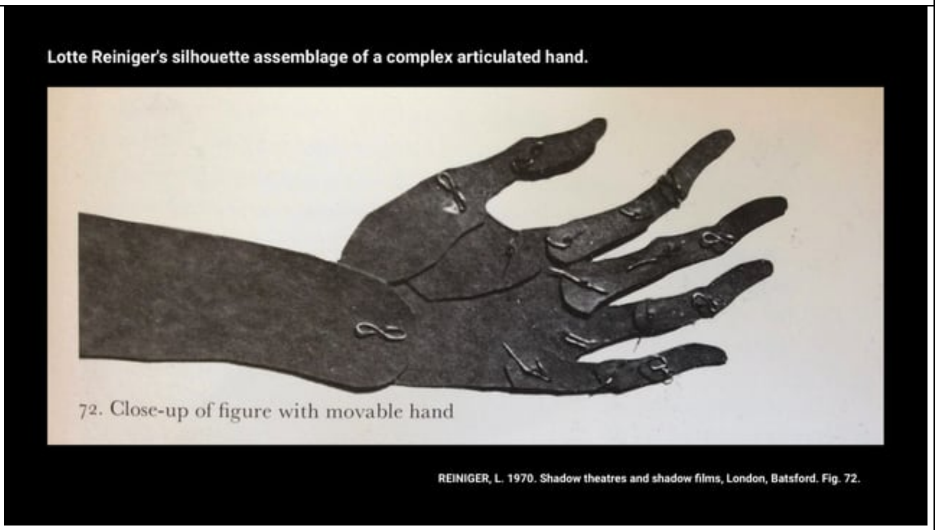
Video 23 Movement and control - FABRIK - Karagöz bird figure	
Chapter Links and Observation Notes	
(00:00)	FABRIK - Karagöz bird figure (1) (Titles)
(00:18)	Expressivity: movement and control Spring network - Karagöz bird figure (1)
(00:29)	Hierarchy of controllers
(00:47)	Multi-touch twist gesture = tilt controller
(00:56)	Double-tap (or click) = eye blink
(01:07)	Twist to rotate on a single controller
(01:15)	Controllers positioned to create tilt per puppet part
(01:24)	Stretch against anchors (stable)
(01:30)	Interplay of joint, control forces and collisions create articulations
(01:36)	Single and parented controllers
(01:52)	Pinch to scale controller (stable)
(02:06)	Emerging pattern - using single touches to pose. Not free flowing but pose-to-pose.
(02:13)	UI - Switch to monochrome
(02:31)	Double-tap / click to blink eye
(02:35)	Spring Network - Flatter Hierarchy
(02:43)	Attempt to control scaling
(02:47)	Physics glitch - foot stuck on friction board
(03:15)	Pose setting and mimetic movement
(03:35)	Expressive framing
(03:42)	UI - Cinematic effects

Video 24 Movement and control - FABRIK - Karagöz bird figure - inverted - glitch	
Link	https://vimeo.com/247689890
File	appendices/a/a1_videos/V24.mp4
Description	Movement and control - FABRIK - Karagöz bird figure - inverted - glitch
Thumbnail	
Chapter Links and Observation Notes	
(00:07)	FABRIK - Karagöz bird figure - inverted - glitch
(00:18)	FABRIK (Inverted) Glitchy
(00:30)	Glitch - Setup problem = trick marionette
(01:01)	FABRIK - Rotation no physics
(01:28)	FABRIK - Bird - Finding poses and Simple and compound transformations
(01:47)	FABRIK - Bird - Rotation no physics (so undynamic. It really doesn't work!)
(02:15)	FABRIK - Bird - Finding poses; Discovery and Flow
(02:38)	FABRIK - Bird - Problem - controller occlusion
(03:01)	FABRIK - Bird - Development: Imagine being able to dynamically re-parent controllers
(03:27)	FABRIK - Bird - Finding poses - Dynamic shapes (morphology)

Video 25 Movement and control - FABRIK - Karagöz bird figure - Scaling glitch	
Link	https://vimeo.com/247689357
File	appendices/a/a1_videos/V25.mp4
Description	FABRIK - Karagöz bird figure - Scaling glitch
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	FABRIK - Karagöz bird figure - Scaling glitch
(00:58)	FABRIK Bird figure
(01:11)	FABRIK - Bird - Disabling scaling - view of figure hierarchy
(01:49)	Multi-touch tilt
(01:58)	FABRIK - Bird - Multi-touch moves
(02:29)	FABRIK - Bird - Discovering poses
(02:40)	FABRIK - Bird - Brief moment of flow

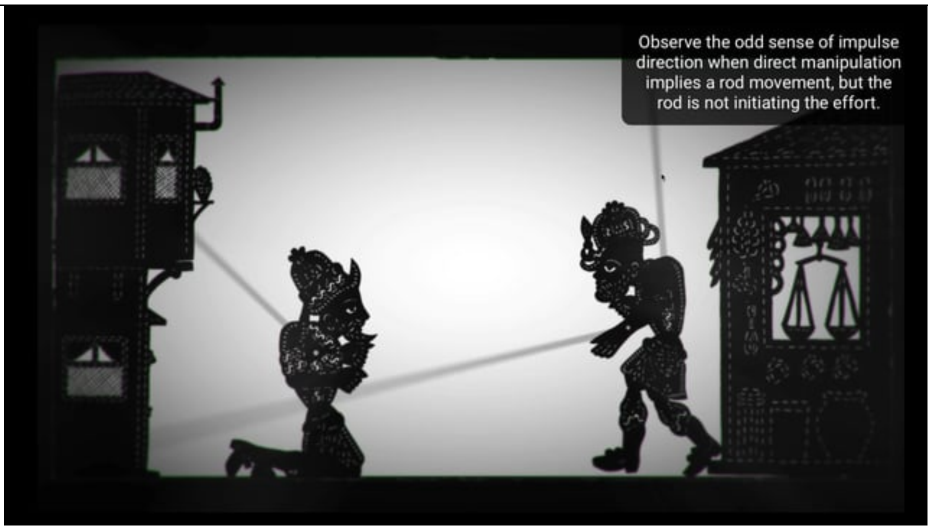
Video 26 Movement and control - Spring network - Reiniger's hand	
Link	https://vimeo.com/247689929
File	appendices/a/a1_videos/V26.mp4
Description	Movement and Control - Spring network - Reiniger's hand
Thumbnail	
Chapter Links and Observation Notes	
(00:09)	Reiniger's Hand: Gesture and the Digital Hand (Titles)
(00:16)	Experiments in gestural interaction with complex jointed silhouettes using touch and motion-based input
(00:22)	Digital reconstruction of Reiniger's hand
(00:34)	Decomposition and Atlas Production
(01:41)	Mapping Finger Motion
(02:36)	Experiments and Observations
(02:42)	001. Leap Shadowgraphs and Controller Demo
(04:04)	002. Two Finger Two-Hand Control - Right Hand
(05:32)	003. Right Hand as Paddle (two points of control)
(06:41)	004. Left-hand one-to-one finger mapping

Video 26 Movement and control - Spring network - Reiniger's hand	
(08:15)	005. Left-hand paddle. Right Hand 1:1 Mapping
(10:22)	006: Left Hand Paddle. Right-Hand Index controls all grouped fingers
(11:53)	007: Right-Hand Thumb Pinch controls fingers and thumb. Left-Hand paddle
(12:36)	008: Mouse Control
(14:45)	009: Right Hand Thumb Index Finger Paddle. Left-Hand fingers 1:1
(16:00)	010. Left Hand Paddle. Right-Hand Index controls all grouped fingers
(17:21)	011. Left-Hand paddle. Right-Hand Thumb Pinch controls fingers and thumb
(18:10)	012: Mouse Control - Creating Gesture Shapes
(19:49)	013: Gesture Shapes: Left Hand Paddle. Right-Hand Index controls all grouped fingers
(21:16)	014: Simple Controllers Complex Movement
(22:49)	015a: Multi-Touch Based Control: Reiniger's Hand
(23:46)	015b: Multi-touch: Pinch to Scale Reiniger's Hand
(25:16)	015c: Multi-touch: Twist to Rotate Reiniger's Hand
(28:34)	015d: Reiniger's Hand Sticky Physics
(29:02)	Fin

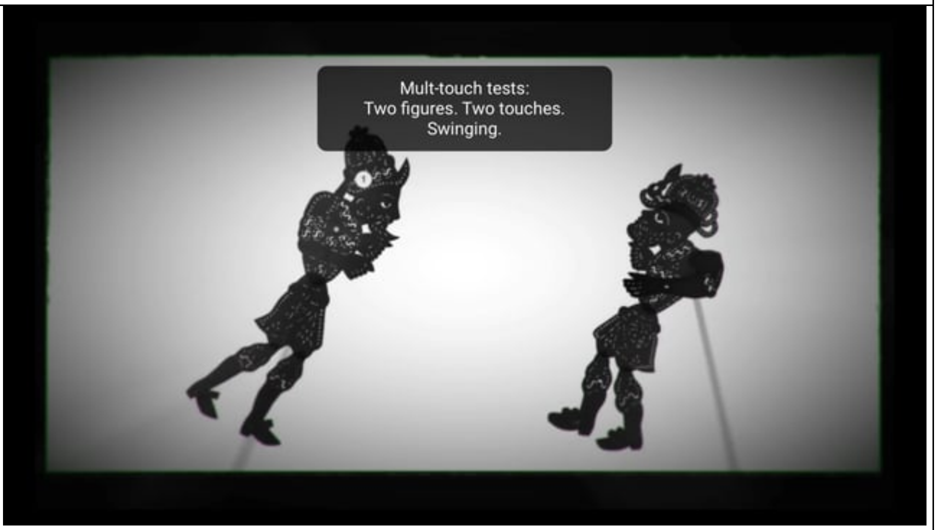
Video 27 Movement and control - Lotte Reiniger's Hand (Process and Leap Motion)	
Link	https://vimeo.com/232826190
File	appendices/a/a1_videos/V27.mp4
Description	Movement and control: Lotte Reiniger's Hand. Demonstration of construction process. Experiments in gestural interaction with complex jointed silhouettes using touch and motion-based input (Leap motion). Fabulous 3D digital hands meet 2D hand meet video hands. A festival of *Ombromani* (hand shadows)
Thumbnail	
Chapter Links and Observation Notes	
(00:09)	Reiniger's Hand: Gesture and the Digital Hand (Titles)
(00:16)	Experiments in gestural interaction with complex jointed silhouettes using touch and motion-based input
(00:22)	Digital reconstruction of Reiniger's hand
(00:34)	Decomposition and Atlas Production
(01:41)	Mapping Finger Motion
(02:36)	**Experiments and Observations**
(02:42)	001. Leap Shadowgraphs and Controller Demo
(04:04)	002. Two Finger Two-Hand Control - Right Hand

Video 27 Movement and control - Lotte Reiniger's Hand (Process and Leap Motion)	
(05:32)	003. Right Hand as Paddle (two points of control)
(06:41)	004. Left-hand one-to-one finger mapping
(08:15)	005. Left-hand paddle. Right Hand 1:1 Mapping
(10:22)	006: Left Hand Paddle. Right-Hand Index controls all grouped fingers
(11:53)	007: Right-Hand Thumb Pinch controls fingers and thumb. Left-Hand paddle
(12:36)	008: Mouse Control
(14:45)	009: Right Hand Thumb Index Finger Paddle. Left-Hand fingers 1:1
(16:00)	010. Left Hand Paddle. Right-Hand Index controls all grouped fingers
(17:21)	011. Left-Hand paddle. Right-Hand Thumb Pinch controls fingers and thumb
(18:10)	012: Mouse Control - Creating Gesture Shapes
(19:49)	013: Gesture Shapes: Left Hand Paddle. Right-Hand Index controls all grouped fingers
(21:16)	014: Simple Controllers Complex Movement
(22:49)	015a: Multi-Touch Based Control: Reiniger's Hand
(23:46)	015b: Multi-touch: Pinch to Scale Reiniger's Hand
(25:16)	015c: Multi-touch: Twist to Rotate Reiniger's Hand
(28:34)	015d: Reiniger's Hand Sticky Physics
(29:02)	Fin

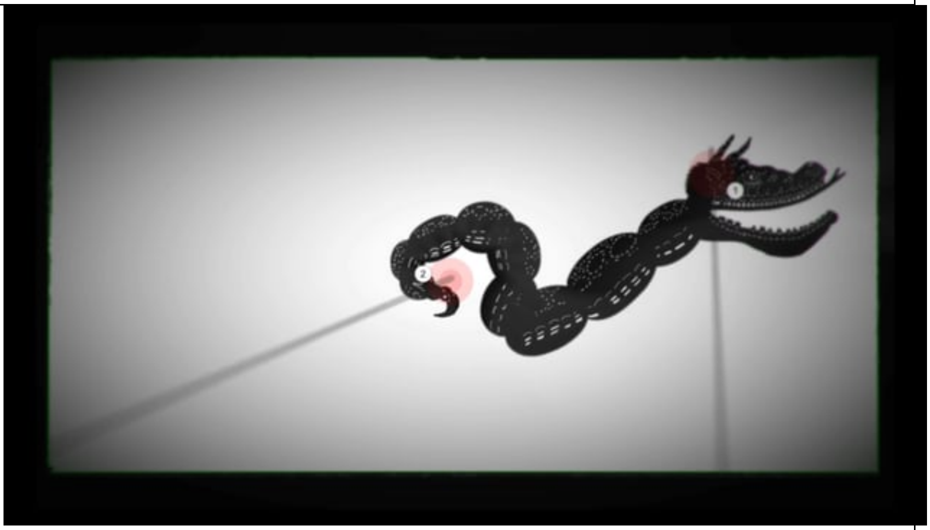
Video 28 Movement and control - [001] Rods	
Link	https://vimeo.com/230807432

Video 28 Movement and control - [001] Rods	
File	appendices/a/a1_videos/V28.mp4
Description	Rods: Experiment [001] Multiple rods. Mono-touch.
Thumbnail	
Chapter Links and Observation Notes	
(00:10)	Title: Movement and Control: Rods: Experiment [001] Multiple rods. Mono-touch.
(00:17)	Multiple rods. Mono-touch.
(00:21)	Hacivat (one rod) and Karagöz (two rods)
(00:28)	Observation: Automatic movement and breathing through physics
(00:49)	Observation: Mouse control and movement through physics
(01:04)	Observation: Accidental Collisions
(01:20)	Observation: Effective top-down control and swing of legs and knee articulation
(01:36)	Observation: Karagöz rest position overbalanced
(01:59)	Observation: Where is the impulse to move coming from?

Video 29 Movement and control - [002] Rods	
Link	https://vimeo.com/230806699
File	appendices/a/a1_videos/V29.mp4
Description	Experiment: Single rods and automated movement
Thumbnail	
Chapter Links and Observation Notes	
(00:10)	Movement and control: [002] Rods Experiment: Single rods and automated movement (titles)
(00:16)	Reference Footage Credit
(00:21)	Reference: Salih Oğuzhan Karagös diş ağrisi / Karagöz has toothache
(00:28)	Observation Springs used for automatic movement and chains of control. 2hrs of coding to connect an arm to a leg.
(00:32)	Karagöz and Hacivat in the ShadowEngine
(00:51)	Observe: Automatic arm movement on Karagöz

Video 30 Movement and control - [003] Rods	
Link	https://vimeo.com/230806776
File	appendices/a/a1_videos/V30.mp4
Description	Experiments with rods: Direction, collision. Mouse, mono and multi-touch.
Thumbnail	
Chapter Links and Observation Notes	
(00:10)	Movement and control: [003] Rods Experiments with rods: Direction, collision. Mouse, mono and multi-touch (Titles)
(00:23)	Visualising the collider objects
(00:28)	Direct mouse control
(00:39)	Direct mouse control of the rod (single point of touch)
(00:51)	Physics and Energy: Direct mouse control pulling head down. Resisted by the rod colliders.
(00:55)	Physics and Energy: Force builds in the physics system...
(01:04)	Touch: Mult-touch tests: direct on figure's head
(01:32)	Touch and Gesture: Mult-touch tests: Two touches. Anchor and rotate. (twist)
(01:45)	Touch Issue: Mult-touch tests: Third touch. Hard to aim. Fingers larger than

Video 30 Movement and control - [003] Rods	
	colliders on iPad surface.
(02:00)	Touch: Mult-touch tests: Two figures. Two touches. Swinging.
(02:07)	Touch: Mult-touch tests: Stable rest positions after pick-up.
(02:14)	Touch: Mult-touch tests: Colliders on rods inhibit certain movements.
(02:25)	Touch: Mult-touch tests: Good stability on pick-up.
(02:30)	Touch: Mult-touch tests: Rod control.
(02:39)	Touch: Mult-touch tests: Two touches on rod. Allows twist.

Video 31 Movement and control - [004] Rods	
Link	https://vimeo.com/230805414
File	appendices/a/a1_videos/V31.mp4
Description	Movement and control: [004] Rods: Rods with and without colliders. No rods. Multi-touch control points.
Thumbnail	
Chapter Links and Observation Notes	
(00:20)	Dragon from Karagiozis: self-collision on.
(00:24)	Observation: the touch points (pink) not the rods are driving the movement
(00:29)	Observation: Effective use of the friction board/floor collider
(00:34)	Observation: Physics glitches
(00:40)	Observation: Very stable stretch
(00:57)	Observation: Not so stable stretch
(01:02)	Physics Glitches: as forces accumulate, the figure becomes less stable.
(01:13)	Observation: In control
(01:18)	Observation: Out of control
(01:29)	Observation: Friction board as pivot

Video 31 Movement and control - [004] Rods	
(01:39)	Observation: Rod orientation out of control
(02:05)	Observation: Skeuomorphic design is tricky to handle. Remove the rods
(02:25)	Observation: Stability of multi-touch controls without physics-based rods
(02:40)	Observation: Fingers are rods in the context of touch
(02:46)	Intended Movement: Undulation: Finding the gesture
(02:59)	Touch: Touch points become anchors = stability on release
(03:20)	Issue: Screen/surface mapping. The dragon cannot leave the screen
(03:28)	Gesture: Two fingers on one hand: Twist gesture. Tricky rotation limits on hand.
(03:55)	Gesture: Single touch. Pace of movements. Spiral gesture
(04:08)	Gesture: Two finger touches. Contra-circular patterns.

Video 32 Movement and control - [005] Rods	
Link	https://vimeo.com/230803662
File	appendices/a/a1_videos/V32.mp4
Description	Movement and control: [005] Rods No rod colliders. Decorative rods. Mono and Multi-touch.

Video 32 Movement and control - [005] Rods	
Thumbnail	
Chapter Links and Observation Notes	
(00:10)	Movement and Control: Rod Experiments [005]. No rod colliders. Decorative rods. Mono and Multi-touch (Titles)
(00:31)	Observation: see the spatial freedom for the rod to move below the friction board. No colliders.
(00:49)	Observation: The rods have 'gravity' turned off. Weirdly, they tend to stay pointing down due to the accumulated mass of the other parts.
(00:58)	Gesture: Finger twist and momentum = head tilting
(01:12)	Accidental movement: Physics glitch = slight bounce.
(01:24)	Tasvir (Set): The Bloody Poplar
(01:37)	Observation: The control zones can be toggled invisible; the first touch may not 'hit' and connect
(02:01)	Mouse Gestures: Mouse resolution is finer. Circular moves. Less twist than a finger
(02:20)	Physics: Dragon body colliders are now turned off. Increased spatial freedom and figure dexterity
(03:09)	Observation: The rod positions are resolved not by physics control. Setup detail

Video 33 Movement and control - [006] Rods	
Link	https://vimeo.com/230802135
File	appendices/a/a1_videos/V33.mp4
Description	Movement and control: [006] Rods: Experiments with rods: Fails, glitches and accidental motion.
Thumbnail	
Chapter Links and Observation Notes	
(00:10)	Movement and Control: Rods [006] Experiments with rods: Fails, glitches and accidental motion (Titles)
(00:22)	Physics Glitch: Emergent movement
(00:48)	Physics Glitch: The spring-joint on the rod is incorrectly configured leading to Hacivat being tormented
(01:06)	Physics Glitch: Karagöz gets skewed on his rod

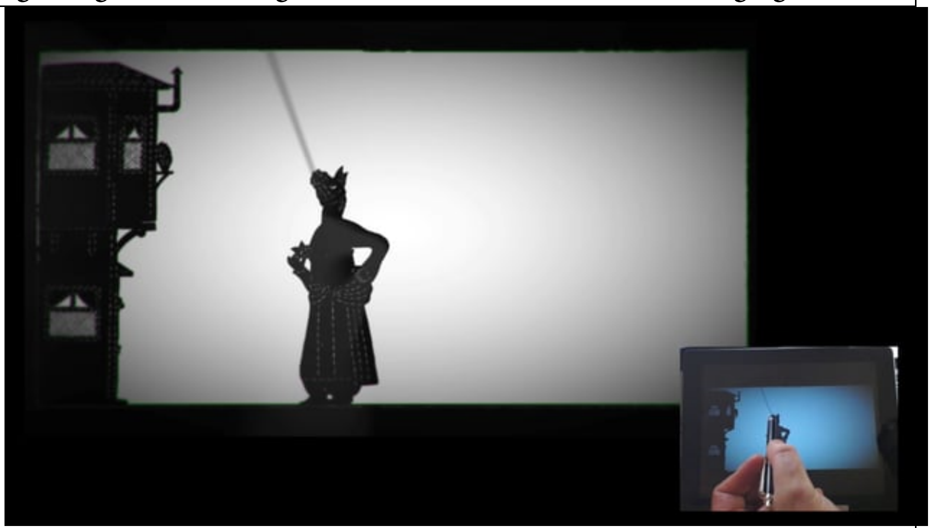
Video 34 Process: From image to animation - Chinese male figure (Chengdu)	
Link	https://vimeo.com/249118843
File	appendices/a/a1_videos/V34.mp4
Description	Thank you to Annie Katsura Rollins for permission to use her photographs. Her fabulous research can be found here: www.chineseshadowpuppetry.com
Thumbnail	
Chapter Links and Observation Notes	
(00:15)	Summary: Photoshop process: digital painting, object segmentation, detailing and atlas layout. Unity process: import, sprite creation, assembling, rigging, physics configuration, adding functionality (visual tools
(14:01)	Skip to demo: Chinese figure-exploring multi-touch and figure dynamics
(00:24)	Photoshop: Isolate and segment puppet parts
(00:34)	Each part is copied to a new named layer.
(00:47)	Close observation informs the decisions as to where to split the figure. Where are the articulations?
(01:03)	We need an awareness of the shape of overlapping elements.
(01:41)	Practise the joint / pivot points.

Video 34 Process: From image to animation - Chinese male figure (Chengdu)	
(01:46)	It is not clear if the foot is a separate element or if it can move. I decide to separate it. We can fix it in place in the game engine.
(01:54)	The clone tool helps re-paint the details occluded by other elements.
(02:10)	The red background helps view the cut-out elements. Unity does post-process textures so although I advise care and attention to detail, the final result is forgiving of pixel level errors
(02:44)	The Chinese figures have such a lot of cutting detail and multiple parts, I am keen to explore a greater range of figures in future projects.
(04:39)	The resolution of this image means some detail is lost in the lace-like cuts and requires painting back in.
(04:55)	Detailing the head. I am uncertain as to what might be cut detail and what may be painted on the figure. The lace-like cut-outs remain 'logical', i.e. no part is isolated like an island that may 'fall out'.
(05:12)	Each segment is complete. The file is duplicated.
(05:22)	Unity: Each part needs to be separated with no overlap when the pieces are cropped into separated sprites in Unity.
(05:57)	The file is saved with a transparent background and imported into Unity.
(06:05)	Each part needs to be separated, named and the centre point adjusted. The centres fall where the pivots are to be placed.
(06:27)	The parts are added and then 'rigged' in Unity 3D. Here are some hard-won workflow tips: zero all positions. Child parts to a zero positioned parent game object. Temporarily parent parts to move them into position
(06:45)	Use the original image as a reference. Sometimes I add pixel sized registration points to align the parts. Here I trust my eye.
(07:31)	Rigging and adding functionality used to take hours. Now, with helper scripts, I can assemble the figure with simple visual effects and full multi-touch support in about 15 minutes.
(07:51)	Rigging the physics: the joints, the colliders, and angular constraints.
(08:48)	Hinges are connected to parts and the hinge joint centres are all checked.

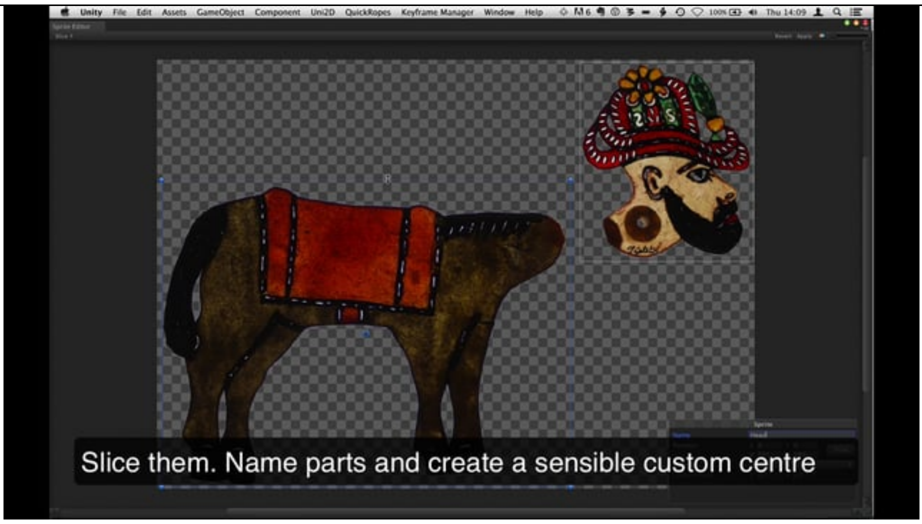
Video 34 Process: From image to animation - Chinese male figure (Chengdu)	
(08:59)	The upper body is set to kinematic-which stops gravity acting on it while we check other joints.
(09:11)	The jitters are caused by the box colliders colliding with each other.
(09:19)	Fixing a rogue centre.
(09:25)	The colliders are turned off and all joints swing free.
(09:39)	Colliders make the figure touchable. In this case, I will need to resize and add multiple colliders per figure part.
(11:12)	The colliders now self-collide in a logical way. More constraints/limits are required, e.g. the head rocks too far each way.
(11:22)	We can edit the source texture. In this case, I fix the shape so there is a smooth edge when the head rotates.
(11:31)	I change the sorting order-so parts that need to be are rendered behind other parts.
(11:40)	I like the way the colliders lead to secondary animation on other body parts. However, this setup limits freedom of movement.
(11:47)	I free the upper body and set it to be animated by gravity and other forces.
(11:56)	Rigging: I add some angular limits to joints.I do it quickly here (for the demo). Also, I wish for more freedom of movement. It helps avoid physics glitches when the figure is touched at more than one point.
(12:15)	Physics-based animation: I really like the repose position.
(12:24)	Manipulation: Mouse control leads to some unexpected articulations.
(12:35)	Multi-touch leads to increased control and orientation. When the object is not touched, it falls.
(12:46)	Single touch and the friction board (floor) help us find poses for the figure
(12:51)	A second touch (it requires gentle movement) leads to interesting secondary animation via physics interactions.
(13:05)	Movement observation: I would be tempted to turn collisions off on the

Video 34 Process: From image to animation - Chinese male figure (Chengdu)	
	right lower arm and experiment with colliders and limits.
(13:12)	Movement observation: The multi-jointed spine leads to very interesting poses. Here, there are no limits applied to its rotation.
(13:38)	Three touches. Nice hand orientation.
(13:50)	Refinement and reconfiguration options are many and their effects compound. Learning to 'play' figure"

Video 35 Digitising the IIM Karagöz collection. A trick or transforming figure	
Link	https://vimeo.com/249113556
File	appendices/a/a1_videos/V35.mp4
Description	From the Karagöz collection of the Institut International de la Marionnette. See: Appendix B: Figure 204 Double Headed Donkey Women A trick or transforming figure.

Video 35 Digitising the IIM Karagöz collection. A trick or transforming figure	
Thumbnail	
Chapter Links and Observation Notes	
(00:08)	Digitising the IIM Karagöz collection: A trick or transforming figure.
(00:20)	Appendix B: Figure 204 Double Headed Donkey Women A trick or transforming figure.
(00:29)	Control: the required gesture for the rotational movement is tricky to find.
(01:22)	Control: I assigned a key to trigger the rotation we need. The rod rotating is distracting.
(01:38)	VFX: Greyscale and monochrome mode.
(01:57)	Control: Multi-touch with two styluses achieve the rotation we require. A tricky gesture to control.
(02:22)	VFX: Monochrome mode enhances the shape change.
(03:00)	Control: Practicing the head rotate gesture. Note it is not a rotation gesture. But an anchor and pull.
(03:36)	Control: Maybe the spring to the original position makes manipulation harder.
(03:49)	VFX: Monochrome mode enhances the shape change.
(04:26)	Control: The keyboard control and automatic rotation appear more

Video 35 Digitising the IIM Karagöz collection. A trick or transforming figure	
	effective.

Video 36 The IIM Karagöz Collection Process and Practice Review	
Link	https://vimeo.com/94315364
File	appendices/a/a1_videos/V36.mp4
Description	A fast-forward through the process of making a multi-touch digital shadow puppet in Photoshop and Unity 3D. The Karagöz material was photographed from a collection and a research residency at the Institut International de la Marionnette (IIM), Charleville-Mézières, France.
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	V36 The IIM Karagöz Collection Process and Practice Review
(00:09)	[1] Practice in the plural
(00:14)	Photoshop: preparing an atlas from the archive collection from the IIM
(00:19)	Figure [207] Karagöz as a horse. Two pieces. Jointed at the neck. Control rod on neck. Appendix B-93.
(00:25)	Photoshop: Extracting the figure. Quick selection tool. Looking for detail.
(01:07)	Photoshop: the level of detail matters later in 'Monochrome' or 'Silhouette mode'
(01:24)	Photoshop: decompose the puppet in the separate articulated parts.
(01:53)	Photoshop: using the pen tool for a precise selection.

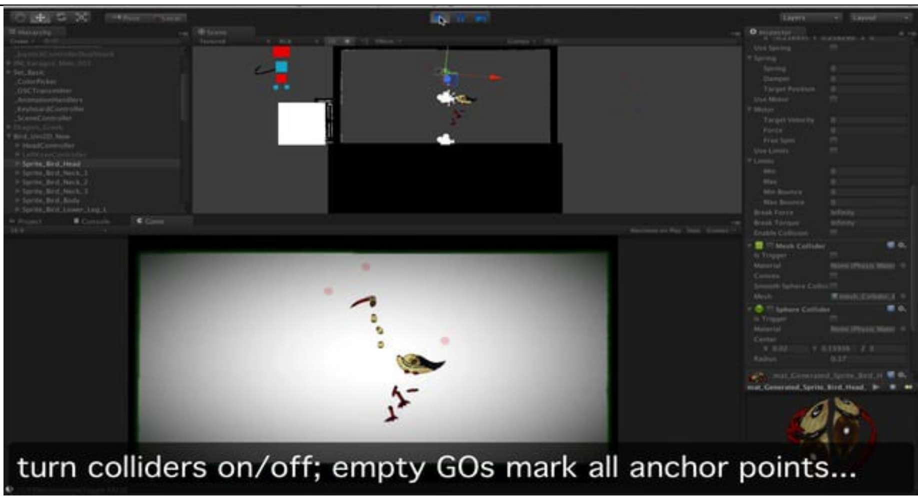
Video 36 The IIM Karagöz Collection Process and Practice Review	
(02:16)	Photoshop: the parts are placed on their own layer for positioning later.
(03:10)	Photoshop: testing rotations using the 'free transform' tool
(03:22)	Photoshop: create an atlas (separate the parts) and save an optimised transparent PNG.
(03:46)	Unity: You have control over the 'world' size of the images after import.
(03:49)	These steps have changed in subsequent versions of Unity.
(03:58)	Unity: Create sprites with centres moved to the pivot point of joints and/or the location of the main rod. This helps the physics system calculate balance and weight distribution.
(04:28)	Unity: the steps for making a jointed figure with touch controls
(04:42)	Unity: Create a parent game object, zero its position.
(04:54)	Drag in the sprites. Modify the units (in the import settings) to resize.
(05:08)	Note: correction. Best to adjust the units rather than scale the sprites.
(05:12)	Add the physics components.
(05:29)	Connect the rigid-body objects to the hinge...
(05:33)	We need some constraints and mass.
(06:17)	Here is a credible repose position.
(06:46)	Demonstrating the touch controllers: spring joints that connect a target to a body part at a specific location on the body part - like virtual strings.
(06:52)	The spring requires strong, dampened attraction. It should be like pulling on a rod rather than a spring. Just enough free movement to 'breathe'
(07:07)	Like strings on a marionette, the control points offer a variety of setups and many configurations.
(08:03)	Setting the springs and the connected anchor settings to position the ends of the virtual spring.

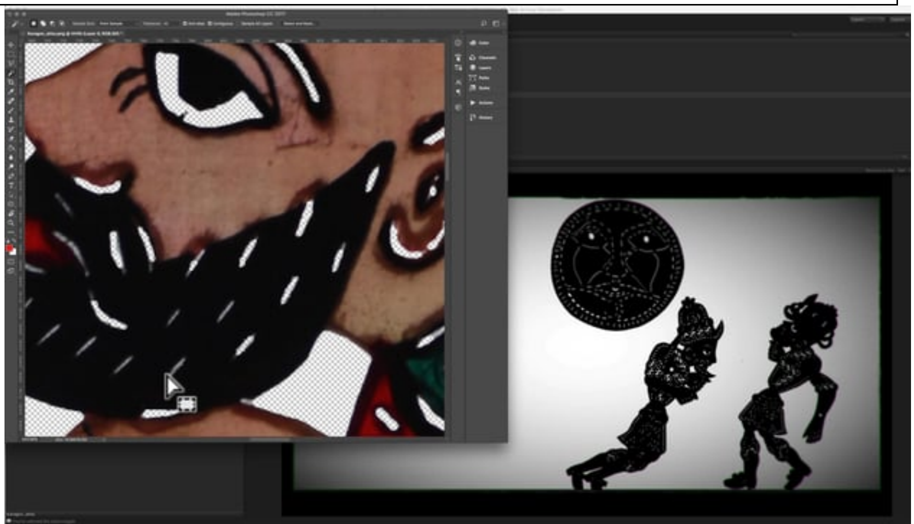
Video 36 The IIM Karagöz Collection Process and Practice Review	
(08:36)	JointGizmo2D is a tool in the asset store that helps visualise anchor and connected anchor positions - and the angle limits.
(09:25)	Once centres are positioned, connect up the control points to the body parts using the hinges.
(09:43)	You can see the spring joints connect to the puppet parts like elastic strings. The spring settings are highly configurable.
(13:23)	The class controls basic visibility, colour states, resting positions, physics properties, movements. In later versions it has been replaced by less centralised code.
(15:30)	After coding: core functionality is added to the new object.
(15:43)	Coding: Next the OSC receiver class sends touch data to the controls.
(15:59)	Our object has two controls - two touches on one iPad.
(16:06)	In subsequent iterations, this coding was refined. One big class was split into smaller units encapsulating single functions/behaviours.
(16:26)	Once connected, touch data is sent the objects through the network (open wifi or a private computer-to-computer network).
(16:59)	Rigging and Configuration: configuring the spring joints is an ongoing endeavour. Each object is different enough, that to find patterns in the settings is so-far elusive.
(17:23)	The configuration is central to the 'feeling' and nuanced manipulation. We are looking for gracefulness and balance.
(18:18)	ShadowEngine 003 Feature Overview and IIM Figures
(18:29)	Multiple iPad sending multi-touch data through a network.
(18:31)	Figure [195] Bird. Nine parts. Joints in neck chain, knees and upper leg. Central rod. Appendix B-89.
(18:34)	Figure [049] Pair of Men with Weapons. Seven parts. Jointed at knees and waist. Single control rod at the centre. Appendix B-43.
(18:36)	Figure [005] Hacivat. Four parts jointed at knees and waist. Appendix B-25.

Video 36 The IIM Karagöz Collection Process and Practice Review	
(18:37)	Figure [166] Laz from the Black Sea. Two parts. Jointed at the waist. Appendix B-83.
(18:39)	Figure [191] Bebe Ruhi. Small drunk. Three parts. Joints at knees. Appendix B-85.
(18:46)	Remote Control: OSC multi-user, multi-character puppeteering.
(18:53)	VFX: Cinematic controls.
(18:59)	Colour and Lighting Modes.
(19:03)	Blur, Motion Blur, Vignetting, Transitions, Noise and FX.
(19:07)	Control: Puppeteer control VFX and a figure.
(19:14)	Colour inversion. A fascinating effect.
(19:33)	Control: real-time performance. Control and capture. The OSC streams can be recorded and replayed.
(19:44)	Scenography and Props: A general purpose script adds keyboard control to scenic elements folding in from any edge.
(19:46)	Props: the human size jars are great props and can be broken. Used in the scene 'The Fountain of Kütahya'. Appendix B-133.
(19:56)	Fin

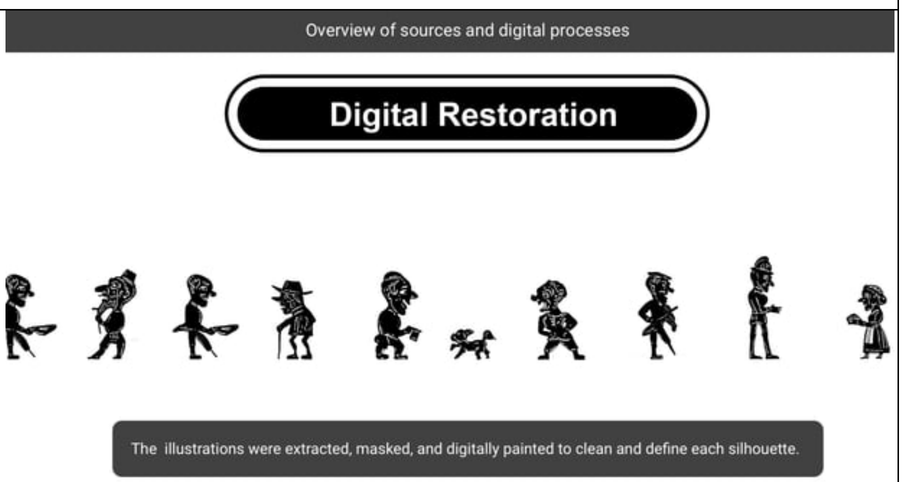
Video 37 Scenography - Animated sets and breakable props	
Link	https://vimeo.com/250707988
File	appendices/a/a1_videos/V37.mp4
Description	Demonstration of the general purpose animation script that helps animate set entrance and exit in the ShadowEngine. Animation timing, random variation, easing, the position can be customised. Also, we see stage properties with breakable features.
Thumbnail	
Chapter Links and Observation Notes	
(00:09)	Scenography: scenery and properties - Animated sets and breakable props
(00:15)	Animated scenery demo
(00:21)	Timings and direction of entry can be set in the script.
(00:30)	Karagöz: Kiosk and house
(00:53)	Colour switching
(01:08)	Karagöz: The garden
(01:20)	Karagöz: The Poplar Tree
(01:37)	Animated door and signage

Video 37 Scenography - Animated sets and breakable props	
(02:06)	Karagöz: Touchable props
(02:26)	Karagöz: Breakable props
(02:40)	Scenery Animation Script Interface

Video 38 Movement and control - Rotation and Scaling - some problems	
Link	https://vimeo.com/232859653
File	appendices/a/a1_videos/V38.mp4
Description	A demonstration of scaling and rotation issues.
Thumbnail	

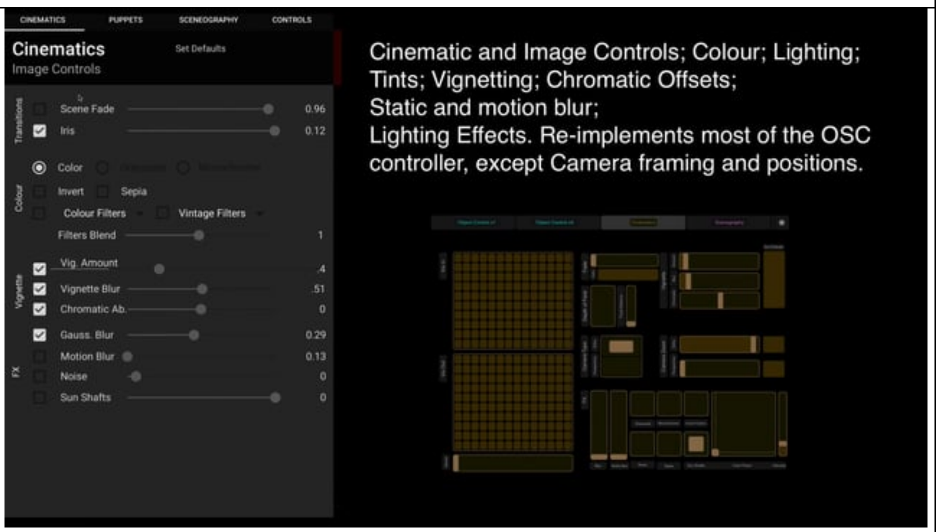
Video 39 Foundation techniques: Karagöz - Digital Painting and Detail Cutting	
Link	https://vimeo.com/232953930
File	appendices/a/a1_videos/V39.mp4
Description	Digital Painting Shadow Figure Details for Silhouettes A screencast of the digital painting techniques used to create rich detailing of the shadow figures. The transparency (or alpha) channel is used by Unity to render the cut-out effects that are painted, etched, cut or carved in leather or cardboard on physical shadow figures and paper-cuts. Creative media archaeological practices: - Collect a set of photoshop pattern brushes sampled from cut patterns on major world shadow traditions - Freeform digital painting, erasing and tracing photographic records with a Wacom tablet - Automatic selection and removal techniques, attempting to automate asset production. Software: Photoshop. Unity 3D.
Thumbnail	
Chapter Links and Observation Notes	
(0:09)	Title: Foundation techniques: Karagöz: Digital Painting and Detail Cutting
(0:26)	Technique: Paint / Erase cut marks

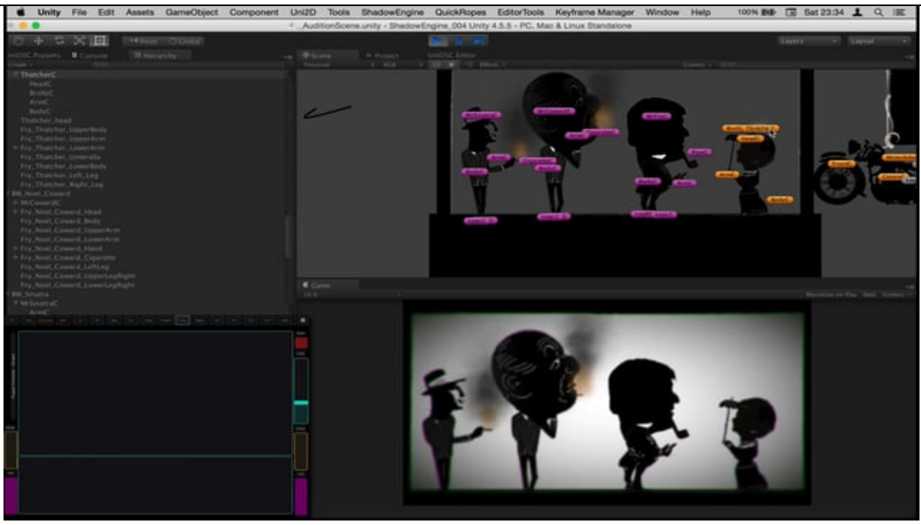
Video 39 Foundation techniques: Karagöz - Digital Painting and Detail Cutting	
(1:00)	Observation: New transparency data loaded live
(1:13)	Idea: Pattern Brush library
(1:35)	Transformation: creative license in modifying the photo textures
(1:59)	Silhouette Mode
(2:05)	Additional Material - Reference to computer-generated paper-put patterns

Video 40 Digital Restoration - Billy Waters	
Link	https://vimeo.com/232265796
File	appendices/a/a1_videos/V40.mp4
Description	Digital restoration: Billy Waters: The London Fiddler (c1850) ShadowEngine 003 and 004, 2013-2014. Unity 4.7.2 https://github.com/iboy/phd_shadowengine_003_2013 https://github.com/iboy/phd_shadowengine_004_2014 A presentation of the digital media archaeology involved in restoring a galanty show (a miniature animated shadow play) from ephemera published by H.G.Clarke and Co. circa 1850. The play-text of "Billy Waters: The London Fiddler" (The Galanty Showman No.18) includes woodcut illustrations of the silhouette characters and sets, and a folded sheet of figures and props to be cut out and mounted on cardboard. Billy Waters was a one-legged fiddler who busked a small living outside the Adelphi Theatre, London. A former slave, Billy Waters traded servitude to join the British navy. He was represented in William Thomas Moncrieff's entertainment "Tom and Jerry, or Life in London" (1821). He died, in 1823, in poverty at the age of 45. He was later cast as a statuette figure in porcelain by the Staffordshire and Derby potteries. H.G.Clarke and Co. published a range of Galanty Show kits in the series 'The Galanty Showman'.
Thumbnail	

Video 40 Digital Restoration - Billy Waters	
Chapter Links and Observation Notes	
(00:09)	Title: Overview of Sources and Digital Processes
(00:21)	Playtext and Illustrations
(00:46)	Photo references
(01:13)	Digital Restoration
(01:55)	Sprite Sheets
(02:16)	Details and Demos: Playtext and Illustrations
(03:12)	Photo References
(04:28)	Digital Restoration
(06:41)	Decomposition
(07:47)	Sprite Sheets
(08:01)	Unity 3D
(08:30)	Character Procession
(09:30)	Character Tests: Jemima. Multi-touch.
(10:03)	Character Tests: Jemima; expressive physics glitch.
(10:29)	Character Tests: Mrs Martin and house. Subtle touch and physics movements.
(11:30)	Character Tests: Mrs Martin and the control UI in Unity.
(12:42)	Character Tests: Tozer the dog
(13:19)	Character Tests: Billy Waters, with Violin.
(13:50)	Character Tests: Billy Waters, with Violin. Multi-touch.
(14:31)	Character Tests: Billy Waters, with Violin. Mouse control.
(14:44)	Character Tests: Billy Waters, with Violin. Testing physics robustness.

Video 40 Digital Restoration - Billy Waters	
(14:58)	Character Tests: Billy Waters, cap in hand. Leg articulation and poses.
(12:16)	Prototype Editor UI

Video 41 User Interface - Demo of prototype remote control UI	
Link	https://vimeo.com/247688458
File	appendices/a/a1_videos/V41.mp4
Description	User Interface - Demo of prototype remote control UI
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Demo of prototype remote control UI (Titles)
(00:07)	User Interface: Prototype for OSC remote control
(00:18)	User Interface: Prototype for OSC remote control
(00:23)	Puppet selection. Controller colour, opacity and visibility
(00:29)	To Do: Sceneography and Miscellaneous controls
(00:33)	TouchOSC Controller re-implemented

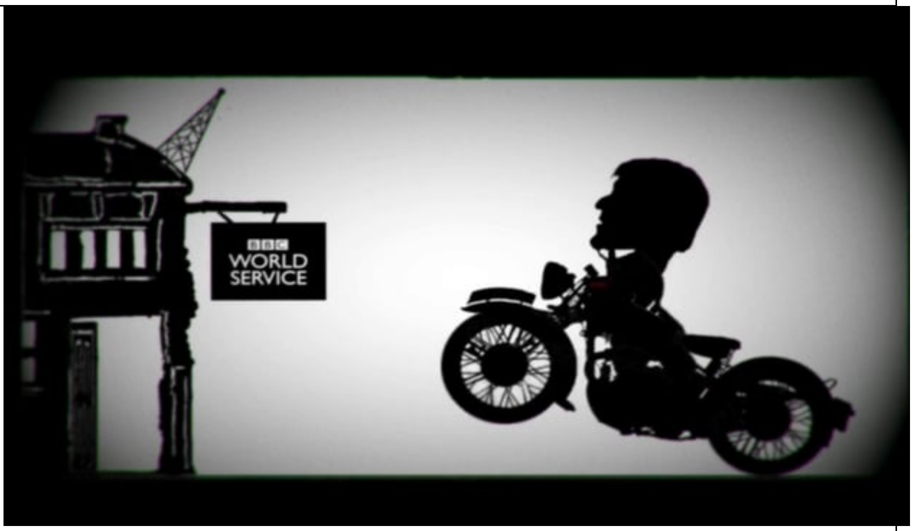
Video 42 The ShadowEngine - Cinematic and Object Control	
Link	https://vimeo.com/115138010
File	appendices/a/a1_videos/V42.mp4
Description	video:the shadow engine: cinematic control project: the fry chronicles: a galanty show creative: Ian Grant, 2014 (cc) web: www.daisyrust.com/yourfry
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	The ShadowEngine: Cinematic and Object Control
(00:11)	Unity editor customised as a play and performance space.
(00:19)	Remote: Cinematic screen: Iris, Camera controls, FX controls
(00:27)	Remote: TouchOSC - Puppet controls. Multi-touch area. Position, rotation and scale. Resting position (hang)
(00:34)	Remote: Camera controller - position and zoom. Other custom FX controls (doors, smoke, flame)
(00:52)	Scene View: Puppets can be arranged and moved in the scene view.

Video 42 The ShadowEngine - Cinematic and Object Control	
(00:58)	Custom UI: performs quick selections and actions.
(01:10)	Scene view panning and zooming does not effect the projected view.
(01:21)	Physics Configuration: the bird figure (in this iteration) has high drag/angular drag settings. Movement should dampen to stillness quickly.
(01:31)	Remote: An iPad running TouchOSC sends signals to the camera fading script.
(01:38)	Remote control: some state changes are automated. Here the fade in/out happens on a toggle.
(01:46)	Remote Control: the Iris controller. Touch control adds a nuance to tempo and pacing.
(02:00)	Remote Control: the iris wipe centre can be positioned by a remote camera operator/director.
(02:11)	Rigging: the bird is an early example of a 'spring network' where control points drag particular points.
(02:19)	Multi-touch: TouchOSC was the first solution I had to multi-user multi-touch controllers. There is a complexity to that solution. Also, direct mouse control can be used.
(02:25)	Remote: Cinematic control can add blur, motion blur, and an experimental depth of field effect.
(02:34)	The blur (when used dynamically) can simulate a number visual anomalies of the surface/shadow interaction.
(02:39)	Exploration: techniques that blend physics-based-animation, pose-to-pose and interactive control are a major focus for the current study.
(02:46)	Motion blur.
(02:47)	Good physics stability.
(02:54)	VFX: Colour, Greyscale and Monochrome modes
(03:42)	VFX - Inversion

Video 42 The ShadowEngine - Cinematic and Object Control	
(03:53)	VFX: Noise and movement effects
(04:13)	VFX: Colour effects: Tints and tones
(04:33)	VFX: Light Shafts offer a neat simulation of shadow projection artefacts.
(04:53)	VFX: The light can be set to follow a specific object, creating an illusion of a second moving spotlight.
(05:07)	Movement and Control: character rotation has proved tricky to solve. Here scaling the character * -1 on the X-axis creates an illusion but lacks grace and visual flow.
(05:23)	Depth and Perspective: The Orthographic to Perspective toggle.
(05:44)	Remote Control: The camera controller. Dollying, zooming, panning. These are filmic conventions often emulated in shadow theatre, although there normally isn't a concept of the camera, but the screen.
(05:54)	VFX and Control: Scaling objects, combined with blur could simulate the dynamic qualities of objects, light source and distance from the screen. However, this operates on 'global' screen space.
(05:59)	Coding: The interpolation of the camera movement between touches is neat and an effect required elsewhere in the system.
(06:04)	Issue: a big problem with TouchOSC: you have to guess how the blank control space is mapped to the screen space. The solution explored in the future iterations saw the recreation of the remote control interface in a separate Unity project where mirrors of the puppet objects themselves
(06:22)	Smoke and fire.
(06:39)	Remote control: Custom controllers can be quickly created and assigned to control effects. Here, smoke and flame parameters can be changed.
(06:50)	Barrel distortion. Chromatic aberration. These neat effects were chosen as they simulate optical phenomena although their application is very dynamic and controllable in digital space.
(07:00)	The offset effect is reminiscent of space between object and surface and variations in the position of the light source. A creative source of play in analogue shadow theatre.

Video 42 The ShadowEngine - Cinematic and Object Control	
(07:29)	There is a quasi-anaglyphic quality to this. There are digital image processing effects that would render anaglyphic edges to the objects. Attention would need to be made on object placement, offsets and the use of a perspective camera.
(07:39)	Image production: the ability to construct complex, interesting images is an unforeseen outcome of the system.
(07:53)	Remote Control: Reset buttons. Return to sane starting values. Each animate-able object requires a 'resettable' state.
(07:59)	Movement controllers: Different layouts exploring different ways of separating and assigning first, second, third, fourth (and more) touches.
(08:08)	Issue: critique of this particular implementation of multi-touch.
(08:20)	Configuring Touch: each touch is mapped to a control point. The control is the anchor of a spring joint attached with a strong attraction to a rigid-body puppet part.
(08:25)	Scaling: transforming body parts.
(08:45)	Issues with scaling.
(08:50)	VFX: Attach/detach objects and props
(09:11)	Configuring Touch: The control is split. The top half controls the whole puppet position, the bottom: first touch = left leg, second touch = right leg. This leads to physics stress.
(09:32)	Touch Configuration: An issue with control surface space to screen mapping.
(09:59)	Characters: a parade of characters.
(10:21)	Distributed remote control: the iPad solution offers the opportunity to share control with other puppeteers or the audience.
(11:41)	Automata: The motorbike: a self-animating property.
(11:51)	Physics: notice pulling the controls below the friction board (the floor) adds tension and energy into the system. Here resulting in a jittering animation.
(12:07)	Critique: the absence of sound

Video 42 The ShadowEngine - Cinematic and Object Control	
(12:49)	Remote Control: each object has a uniquely configured control screen.
(12:55)	Remote control: Useful view of the visual feedback the control environment gives. Advantage to 'fixed touch configuration': you don't have to aim at a particular controller.

Video 43 YourFry Extract 'The World Service'	
Link	https://vimeo.com/115156168
File	appendices/a/a1_videos/V43.mp4
Description	Project: The Fry Chronicles: a Galanty Show Creative: Ian Grant, 2014 (cc) Web: http://wwwdaisyrust.com/yourfry Also see: http://www.yourfry.com/ Unlike the project introduction video, the animated scenes have not been sped up, giving a greater sense of the pace and dynamics of the system. With more performers and rehearsal, the pace can be made quite tight.
Thumbnail	

Video 44 YourFry Extract "Introduction"	
Link	https://vimeo.com/114836492
File	appendices/a/a1_videos/V44.mp4
Description	My response to the YourFry digital storytelling challenge takes the form of a Galanty show nodding back to the day when everything was 2D. A Galanty is 'a pantomime shadow play, especially one in miniature using figures cut from paper.' With my performance animation software, the ShadowEngine, the Shadow puppet is given a digital make-over using a games engine and touch surfaces (iPads) as puppet and cinematic controllers. Multiple performers or interested audience members take control of the digital puppet show using touch surfaces like iPhones or iPads and rehearse or casually respond to the story-making and improvised flow. The Fry Chronicles, shaped by Mr Fry's polymathic presence, with a fusion of vaudeville, musical theatre, debauchery, indulgence, geekery and the celebration of old and new media chime with my inner media archaeologist and 'The Fry Chronicles' exemplifies the material for which the ShadowEngine was created. Note: there is dual or mis-spelling of 'galanty' or 'gallanty'
Thumbnail	

Video 45 The ShadowEngine - Process	
Link	https://vimeo.com/114829064
File	appendices/a/a1_videos/V45.mp4
Description	The Fry Chronicles: A Digital Galanty Show. A walkthrough illustrating some of the key features of the ShadowEngine as explored in my 'YourFry' interpretation. video: the shadow engine: process project: the fry chronicles: a galanty show creative: Ian Grant, 2014 (cc) web: http://www.daisyrust.com/yourfry Note: the animation in the introduction video is sped up slightly. You get a better sense of tempo and control in this video.
Thumbnail	
Chapter Links and Observation Notes	
(00:01)	The Fry Chronicles: A quick reworking of assets to demonstrate the application of the shadowengine to other projects.
(00:08)	Performance Layout: Note the multiple iPads controlling puppet figures and scenography. There is a custom UI written for Unity to facilitate the selection and animation of characters. The Output Screen is moved to an external monitor/projector and the control UI remains in the performers space, unseen by an audience.
(00:16)	Slider controls object scale. Limitation: one element can be scaled, otherwise the physics breaks.

Video 45 The ShadowEngine - Process	
(00:21)	The OSC controller touches are mapped to different controllers around the puppets. These are not generalised yet, but unique mappings. User testing revealed issues with the TouchOSC interfaces.
(00:24)	Custom Actions: some puppets have features. Here a removable and replaceable cigarette.
(00:32)	VFX: Smoke and flame.
(00:46)	OSC: Multi-touch. It works but not having visual targets in the TouchOSC UI is tricky. It leads to physics issues.
(00:49)	Movement: There needs to smooth interpolation between the 'touch-point' and the location of the puppet controller. Currently, it jumps. The code for this has been completed and works in the camera pan and dolly code elsewhere.
(00:51)	Movement: multi-touch is working. But the feeling is disorientating. Hit the rotate figure button while touching leads to a glitch.
(00:56)	Play-space: Note the play space can be zoomed in or out. This is a most useful feature in performance. Note also the zoom works independently from the projected screen output.
(01:08)	Glitch: the parenting of the smoke and the smoke physics behaviour is a little odd.
(01:22)	OSC Multiple controllers: Here the second controller is connected to a second character.
(01:24)	Movement: the single touch 'walk' is little more than jigging, and the movement is a little crude.
(01:29)	Scaling: the head scaling is a proof of concept. Whole figure scaling is elusive (with the physics solution available at the time of production.
(01:35)	These figures and scenes are part of an interpretation responding to the YourFry digital storytelling challenge by Stephen Fry and Penguin.
(01:37)	The work was reviewed by Stephen Fry, Tim Berners-Lee, Will Gompertz and a panel from Penguin.

Video 45 The ShadowEngine - Process	
(01:45)	FX: removable/fixable elements. The code is general an can be set up per object and target 'hotspot'. The physics settings require taming.
(01:52)	Scenography: note the image in the background providing texture. Any transparent image can be added (quickly) to the ShadowEngine allowing quasi-improvised storytelling and scene setting.
(01:53)	OSC Controller 1: Is switched to a third figure.
(01:58)	Multiple puppeteers on iPads control figure movement, rotation, scaling, and objects. Cinematic elements: transitions, colour, light, atmospherics, camera movement are also under real-time control.
(02:01)	VFX: You can see the sun flare / shadow effect (in yellow). The character casts a broken shadow. The verisimilitude is effective.
(02:14)	Performance: Objects can be quickly created, added and rigged ready for introduction into improvised vignettes and compositions.
(02:33)	Performance: using the Unity interface in this way for performance presents opportunities: here multiple selections can group figures and they can be manipulated (by the mouse) all at once.
(03:04)	Potential: Image making and composition
(03:05)	VFX: There is a certain verisimilitude and at the same time logical absurdities presented (here for example) by the glow of the flame.
(03:17)	Scenography: Keyboard presses are mapped to the appearance of images - here caption cards and scenic frames. Aesthetically, I'm remixing a sense of the projected images of silent film with live shadow theatre performance.
(03:37)	VFX: Detaching/re-attaching objects. There is a contact zone on the hand and the head.
(03:59)	VFX and Props: The motorbike depends on physics and friction collisions to move.
(04:01)	Performance: using Unity in performance like this has interesting analogies: consider all the objects stored off-stage.
(04:04)	Physics glitch: self-animating motorbike.

Video 45 The ShadowEngine - Process	
(04:16)	UI: the custom buttons offer quick access to VFX and other action: here exhaust smoke.
(04:37)	Control: I've set up a attach/detach target zone on the seat and the rear of the figure. I'm attempting to connect them together to move as one.
(04:57)	Control: OSC controller 1 is now mapped to the motor-bike. The mapping scale makes movement very sensitive and hard to control.
(05:06)	Movement and Control: with practice multi-touch control tilts the motorcycle into wheelies and endos.
(05:55)	Movement: the wheel movement is effective. The smoke, rotation and sensitivity all require re-thinking.

Video 46 Foundations- Animata and Photoshop. Mesh-based image warping tools for real-time animation	
Link	https://vimeo.com/249657025
File	appendices/a/a1_videos/V46.mp4
Description	A short demonstration of how mesh-based image warping can be used in real-time animation. Manipulating silhouettes is effective because image stretch and distortion is not apparent. The video ends (07:42) with an early example I made of multi-touch control happening on a shadow puppet figure in Animata. “Animata is a real-time animation software, designed to create interactive background projections for concerts, theatre and dance performances. The peculiarity of the software is that the animation - the movement of the puppets, the changes of the background - is generated in real-time, making continuous interaction possible. This ability also permits that physical sensors, cameras or other environmental variables can be attached to the animation of characters, creating a cartoon reacting to its environment. For example, it is quite simple to create a virtual puppet band reacting to live audio input, or set up a scene of drawn characters controlled by the movement of dancers.” (Source: https://github.com/n1ckfg/Animata)
Thumbnail	
Chapter Links and Observation Notes	
(00:00)	Foundations: Animata and Photoshop. Mesh-based image warping tools for real-time animation

Video 46 Foundations- Animata and Photoshop. Mesh-based image warping tools for real-time animation	
(00:15)	Animata, Kitchen Budapest (2008)
(00:27)	Mesh generated over an image. The dots are moveable vertices that will distort the image.
(00:35)	Clicking on the vertices locks them into position.
(00:37)	Animata helps create 'bones' that create movable parts attached to images or in this case sub-parts of an image.
(00:52)	Selecting bones: you then assign vertices to create a zone of influence over the image.
(01:21)	Assigning vertices to bones: Assigned carefully, the bones can deform a local set of pixels.
(01:43)	In view mode, you can select and move bones. Bones can be moved via the mouse or changing values being passed into Animata via Open Sound Control (OSC) from almost any human interaction device.
(01:49)	Even my quick set up lets expressive shape transformation happen.
(02:19)	Here the distortions are used to create new silhouette based on the initial image. These real-time transformations can be animated.
(02:59)	Animata, Kitchen Budapest (2008). Showreel. Sound activated animation. http://animata.kibu.hu/
(06:34)	Adobe Photoshop Puppet Warp (2010)
(06:40)	Similar image warping tools to Animata in Photoshop. Not normally a real-time performance tool.
(07:42)	Animata: Karaghiosis snake shadow figure Multi-touch control with TouchOSC via Quartz Composer (2012)
(07:50)	Multiple images laid out in Animata
(07:59)	Animata supports creating geometry with vertices and triangles.
(08:05)	Animata supports creating joints and chains of bones that will move/distort the geometry.

Video 46 Foundations- Animata and Photoshop. Mesh-based image warping tools for real-time animation	
(08:19)	You can move the joints and bones with the mouse or using Open Sound Control (OSC) to send values to Animata that will control the position of the elements.
(08:42)	I use Quartz Composer-a visual programming environment-to receive, process and send OSC signals.
(08:51)	Walkthrough the Quartz composer patch
(09:04)	Test the bounds of the touch input
(09:24)	The jump is due to congestion on the wifi network. Computer-to-computer networks tend to work better with less 'noise'.
(09:42)	Animata smooths the movement and gracefully deals with stretch. There is no simulation of physics in this example.
(09:53)	Animata has a basic gravity physics simulation. I added a third control point allowing tilting of the head.First touch = tail Second touch = nose Third touch = neck

APPENDIX B – MONOGRAPH: KARAGÖZ AND THE SHADOWENGINE

Digitising the Karagöz Collection of the Institut International de la Marionnette

Photo-documentation, annotations and synopsis.

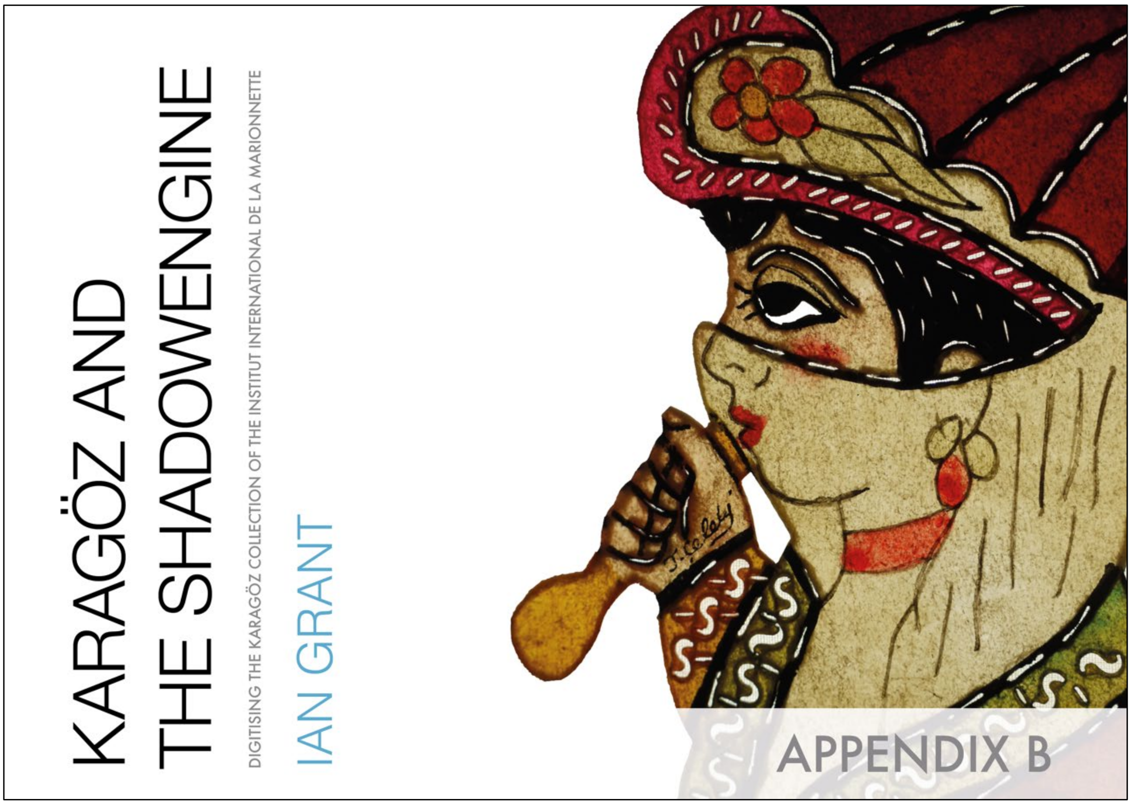


Figure 39: Cover of Monograph: Karagöz And The Shadowengine

Appendix B is a separate printed monograph[1]. It presents material digitised from the collection of the Institut International de la Marionnette[2] (IIM) and sets it within the context of the broader ShadowEngine project. With the generous support of a three week research residency and grant from the IIM, I photographed, processed, and 3D modelled a set of Turkish Karagöz figures, tasvirs[3], and stage properties. The IIM hold approximately two-hundred and twenty-two Turkish Karagöz shadow figures, props and sets commissioned by Margaretta Niculescu and made by the puppet maker J. Çelebi (the signature on the figures) for a touring exhibition in 1982. Long since in storage, these figures have been carefully photographed and processed to enable them to move again, albeit in virtual space. Many of the figures resemble stock Karagöz 'molds', found in other European collections.

Photography

The objects were lit either with a light box or rear-illuminated by day-light when the mounted object collections could not be dismantled from presentation boards.

Textual and Visual Research

I researched the figures and the Karagöz tradition through a variety of textual and visual sources. The IIM lacked contextual information on the identity of these particular objects and provided only a few scene descriptions (in French) for figures that had been collected into vignettes to display stories and scenarios.

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[1] A print-ready PDF can be downloaded here: http://www.daisyrust.com/shadowengine/thesis/-appendices/b/Appendix_B_Karagoz_and_the_ShadowEngine_HiRes.pdf

[2] Institut International de la Marionnette, Ecole Nationale Supérieure des Arts de la Marionnette (ESNAM). 7 place Winston Churchill. 08000 Charleville-Mézières, FRANCE.

[3] 'Tasvirs' are objects that are mostly motionless, though some are partially animatable.

Each figure has been identified and provided with a description of the character, construction and control. A variety of scholarly sources were used to identify characters and likely plots of the other vignettes: in particular And (1975) and Şenyer (2015). Myrsiades and Myrsiades (1992) chart the inter-cultural relations of Karagöz (Turkey) and Karagiozis (Greece), the migration of shadows from the East and detail the exchange and variations of plots and scenarios. They outline Turkish Karagöz plots that are not published elsewhere in English.

Contextual summaries for the chapter introductions were informed by Smith (2004), Aykan (2015), Oztürk (2006) and Gassner (1970). Aykan (2015) makes close reference to the cultural-political implications of UNESCO inscribing *Karagöz* on the Representative List of the Intangible Cultural Heritage of Humanity on behalf of Turkey. In listing *Karagöz*, and other endangered world cultures, UNESCO encourages acts of preservation and safeguarding. Doing this through digital means is a credible way to appropriate, explore and extend cultural practices otherwise laden with nationalistic and often misogynistic values.

Video References

We can appreciate the static imagery in the monograph, but the intent was to make the figures move and, if the interaction experiments allow, exhibit emergent character and liveliness in performance for an audience. The following items in the video portfolio show the production processes and characters in action:

Video 22 Video 23 Video 28 Video 29 Video 30 Video 31

Video 32 Video 33 Video 35 Video 36 Video 37 Video 38

Contribution

The monograph will have a life beyond the thesis. It is a near unique[4], comprehensive photo catalogue of a Karagöz collection. After the thesis, it will require wider consulation on the accuracy of the identifications and scene descriptions. The monograph will be updated and, with the thesis, deposited in the IIM's collection.

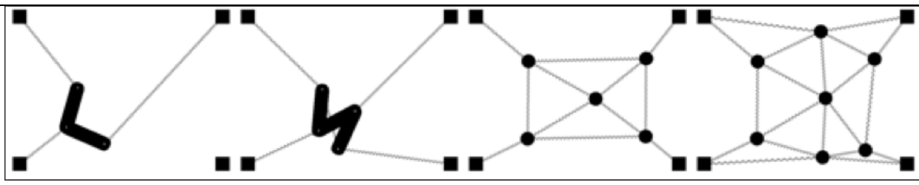
[4] A scarce volume, with a short print run, by Ozcorekci and Zeynep GOL, O. & ZEYNEP, N. 2008. *Colours of Shadow,* Ankara, T.C. Kultur ve Turizm Bakanligi Yayinlari. was produced to support the Turkish application for listing Karagöz as intangible cultural heritage with UNESCO.

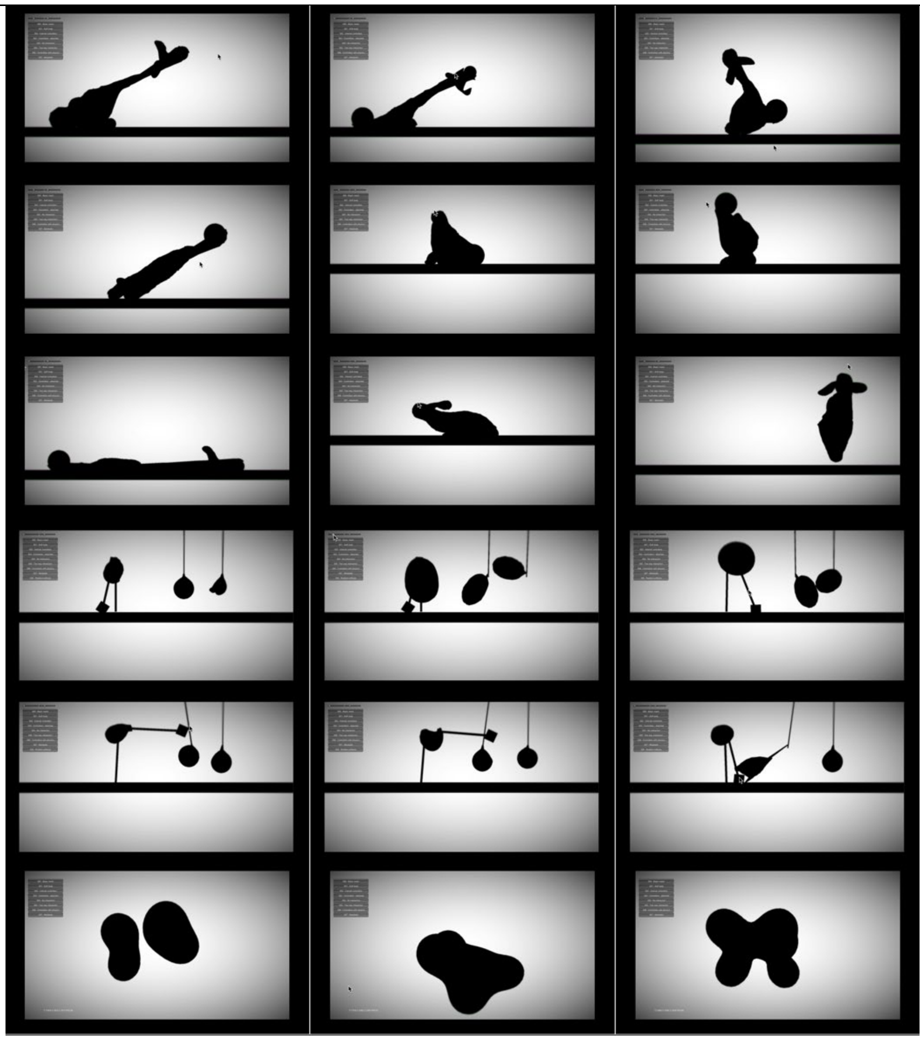
APPENDIX C – CODE REPOSITORIES

The creative coding projects are available in reposititories on github.com and are also archived on the accompanying USB. The repositories store working Unity 3D projects and all build and run if the project dependencies are satisfied. Git and Github are tools that enable project documentation, collaboration and version management. The ShadowEngine project version changes mark step-changes in the development or transitions where Unity 3D had major updates that required significant adaptation of the code and processes.

PhD Master Repository Coding Projects	
Link	https://github.com/iboy/PhD
File	appendices/c/
Description	The master repository contains all the main Unity projects. You can read full descriptions of each by visiting the projects on github. The Unity 4 projects were originally built with Unity Pro 3 through to the current release. I include the most stable and evolved releases in the PhD submission. These projects are frozen at the point of submission. Development continues on other branches in the repository.

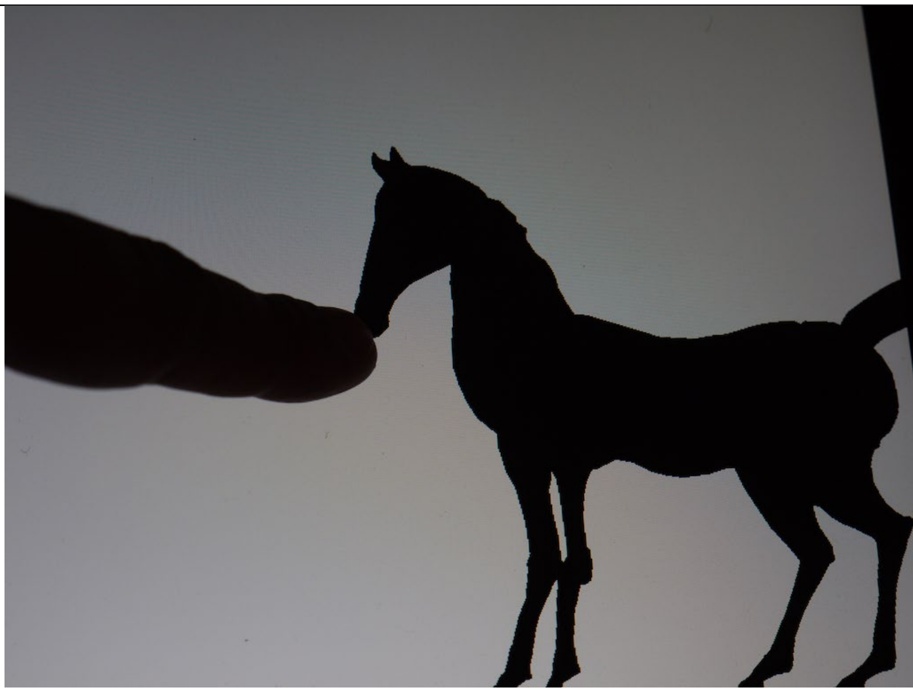
PhD Master Repository Coding Projects	
Thumbnail	

Springies 2011	
Link	https://github.com/iboy/phd_springies_2011
File	appendices/c/phd_springies_2011/
Description	Foundations - Play with spring dynamics, in combination with user interaction and rigid body objects. Created in Unity Pro 4 (2011) Updated to Unity 4.6.7
Thumbnail	

Softbodies 2012	
Link	https://github.com/iboy/phd_softbodies_2012
File	appendices/c/phd_softbodies_2012/
Description	Foundations - Play with soft body dynamics, in combination with user interaction and rigid body objects. Created in Unity Pro 4 (2012) Updated to Unity 4.6.7
Thumbnail	

ShadowEngine 002: 2012	
Link	https://github.com/iboy/phd_shadowengine_002_2012
File	appendices/c/phd_shadowengine_002_2012/
Description	**Software:** Unity 4.7.2 - Original multi-touch iPad prototype. **Figures:** Karaghiozis; a Reiniger horse; a Reiniger female figure; Wayang Kulit. **Features:** Multipart, jointed 3D figures. iPad publishing; Multi-touch puppetry controls; Tests different approaches to figure assembly; Key bindings to experiment with angular constraints of root objects. Visual design: whole screen blur, vignetting, chromatic aberration, depth-of-field; Figure material settings (colour, grayscale, silhouette); **Change-log ShadowEngine 002** (1) Added multi-touch support on all figures, currently works with orthographic cameras. (2) Visual design: added several post-processing rendering effects and figure rendering controls: Vignetting: screen corner blur; subtle vignette shape and shadowing; Full screen blur; Depth of field (only works with a perspective camera) - attempting blur per object. Key-binding D Motion blur; Grayscale, silhouette and colour switching for coloured figures (In

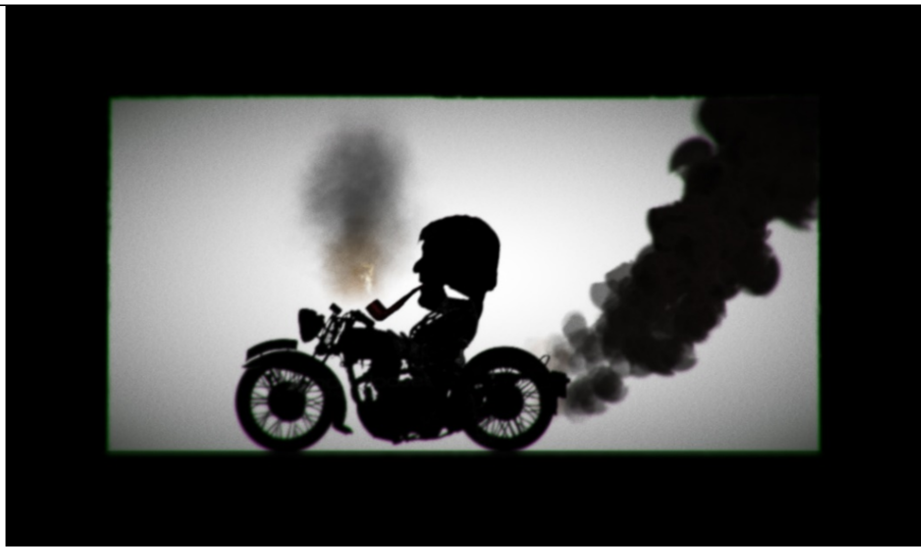
ShadowEngine 002: 2012	
	Karaghiozis scene key-bindings: Z X and C) (3) For demonstration purposes added a 'Touch-tracker', to visualise multiple touch points on live screen-captures (only works in Orthographic mode). (4) For demonstration purposes added 'Camera Switcher', to toggle between 'Orthographic' and 'Perspective' camera types (key-bindings: P). (5) For demonstration purposes added a keyboard utility to change at run-time 'Configurable Joint' settings: set angular limits on X, Y and Z. (default key-bindings: Q W E). Tweaking the 'angular motion limits' significantly changes the animatable and physics driven behaviours of the figures. The default settings for the main body part of the Karaghiozis figure's configurable joint's angular motion (per axis XYZ) is 'locked', 'limited', 'locked'. This stops angular motion around the X and Z axis - note he doesn't bend at the waist and the piece is always upright. 'limited', 'limited', 'locked', with no angular constraint on Y - lets the figure rotate on the Y axis (flipping) using friction and momentum. Free, locked, locked - lets the figure somersault around. The Wayang Kulit needs the following setting: Limited (-10,10), free, locked. (6) Changed the mass of the two-part Karaghiozis figure, seeking a better resting balance.

ShadowEngine 002: 2012	
Thumbnail	

ShadowEngine 003: 2013	
Link	https://github.com/iboy/phd_shadowengine_003_2013
File	appendices/c/phd_shadowengine_003_2013
Description	**Unity Pro 4.7.2 Project** Features: Early Billy Waters, Karagöz, UniOSC touch control, animated sets
Thumbnail	

<table>
<tr><th colspan="2">ShadowEngine 004: 2014</th></tr>
<tr><td>Link</td><td>https://github.com/iboy/phd_shadowengine_004_2014</td></tr>
<tr><td>File</td><td>appendices/c/phd_shadowengine_004_2014</td></tr>
<tr><td>Description</td><td>Unity 4.7.1. 2014.

Highlights: Your Fry, Billy Waters, Karagöz, UniOSC, other FX.

1. Billy Waters
2. Your Fry
3. Karagöz
4. UniOSC
5. Cinematic effects
6. Custom Unity editor UI to enable real-time performance control</td></tr>
<tr><td>Thumbnail</td><td></td></tr>
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ShadowEngine 055: 2017	
Link	https://github.com/iboy/phd_shadowengine_0055_2017
File	appendices/c/phd_shadowengine_055_2017
Description	Unity 5.5 2017. The refactoring and update for Unity 5. New UI. Client and Remote app. Multiple Figures rigged with Direct manipulation, spring networks and FABRIK control rigs. Full UI with state / preference saving; Replicated the Touch OSC interface in a Unity iPad app;
Thumbnail