Devising Interactive Theatre: Trajectories of Production with Complex Bespoke Technologies

Andrew Bluff, Andrew Johnston Animal Logic Academy / Creativity & Cognition Studios University of Technology Sydney {andrew.bluff, andrew.johnston}@uts.edu.au

ABSTRACT

This paper presents a case study of a long-term collaboration between a physical performance company and interactive digital artists. The collaboration has resulted in the creation of five major performance works which have toured internationally over several years. We argue that the interactive systems can be considered a 'material' which changes over time, shaping performer actions and being shaped by them in return. Based on detailed interviews with key stakeholders and our own personal reflections, we have identified several 'trajectories' that have evolved over the duration of each individual production and the entire body of work. These trajectories address a number of perspectives including the way performers interact with the system, the relationship between the dramaturgy and the interaction palette and the way the stakeholders conceive of the interactive system. The evolution of the technology itself has also been examined in terms of aesthetic capability, performance robustness, operational cost and complexity across the entire duration of the collaboration.

Author Keywords

Interaction; Physical Theatre; Trajectories

CCS Concepts

•Applied computing → Performing arts; •Humancentered computing → Empirical studies in HCI; Empirical studies in interaction design;

INTRODUCTION

In 2010 the artistic director of Stalker Theatre, an Australianbased physical theatre company, approached Andrew Johnston, an interactive artist/researcher from the University of Technology Sydney, to add an interactive digital component to their latest project, *Encoded*. The show premiered in 2012 and has since toured throughout Australia, Europe and Asia, marking the beginning of a collaboration spanning eight years and five major productions to date. The interactive system built for *Encoded* was employed throughout the entire collaboration, consistently evolving and adapting to the needs of each new production.

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The relationship between performer and interactive system has also shifted alongside the performance genres, interaction aesthetic and staging design of each new works. This paper examines these trends and influences that have shaped the collaboration over the past eight years.

This paper provides a brief examination of related projects in the interactive theatre space, before introducing the notion that interactive systems are a 'soft' or malleable material which changes over time. We then argue that observing the human and non-human stakeholders on equal footing can be helpful when unpacking these complex collaborations. The performances themselves are described before finally discussing the relationships between interactive technology and creative practice in these works. These relationships are shown to evolve over time as trajectories which are identified and discussed over a number of different timescales.

BACKGROUND

There are many ways in which physical theatre performances can be deemed to be 'interactive'. Costumes can be embedded with responsive electronics such that they transform during the performance of a theatrical work [17]. Interactive props and technological devices which react to proximity and movement can be used to highlight key narrative points within theatrical plays [16]. The actual creation of the performance itself can be an interactive process between artist, technologists and willing audience participants [7]. In immersive theatre, the audience is placed in the middle of the stage and can often choose whether they interact with the surrounding physical space, narrative structures or even human actors as the audience become active participants in the work [28].

Many of these diverse interactive techniques have been explored throughout the collaboration with Stalker Theatre including virtualised projected costumes in *Encoded* [19], immersive theatre that surrounds a participatory audience in *Creature Interactions* [5], and interactive technologies that portray key narrative structures in *Creature* [6]. While these works contain various types of interactivity, the core mechanic of the entire collaboration relies on an audio-visual system reacting to motion-tracked human performers in real-time. This mechanic is reminiscent of David Rokeby's *Very Nervous System* [33], *Mortal Engine* by Chunky Move [24] and numerous works by Troika Ranch [20].

Different types of interactivity within theatrical and dance productions have been well documented, but there is little research into how these interactive systems and their relationships to the performers evolve over time. This evolution can occur

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throughout the lifespan of a production and across numerous projects in a substantial body of work. There are, of course, a few notable exceptions. In 2003, Stevens et al [31], presented an in-depth case study of Red Rain, identifying 'phases of development' that began with improvisation and the development of improvised phrases which were then "experimented with, sequenced and re-sequenced in various combinations" [31, p.311]. Examining a body of six interactive dance works spanning a three year period, Latulipe et al [23], revealed that the exact time in which technology and technologists were introduced to a production could change the trajectory of development, affecting the choreography and nature of production. Following a decade of participatory theatre and mixed reality performances with the Mixed Reality Laboratory, Benford and Giannachi [2], have identified a number of trajectories that have inhabited their works during this period. These trajectories focus largely on the audience journey throughout their productions.

Examining the trends exhibited during the creation of individual performance works can provide insights into the development process and how the contributing artists relate to the interactive technology. Plotting the trajectory of these trends over multiple works can highlight how these processes and relationships evolve over the duration of a long-term collaborative partnership.

BECOMING MATERIAL

Devendorf et al [9], argue that forms can emerge organically from a creative 3D-printing practice where human and nonhuman actors interact freely and the material itself is permitted to take an active role in the process. In the context of dance and physical theatre, the interactive audiovisual system itself can be seen as a kind of 'material' which the artists are exploring. The appearance and behaviour of these materials inevitably change over time. This is true of all materials, including those characterised as 'hard' or tangible such as wood or concrete, but is especially true of 'soft' materials such as those which involve digital technologies. Bergström et al [4] use the term 'becoming material' to describe new kinds of physical materials which are able to respond rapidly and significantly to their environments. Examples include 'memory alloys' - metals which 'learn' a particular shape when heated and can switch between their previous shape and the 'learned' shape as the temperature changes - as well as materials which are controlled using digital technologies, such as glass which can be made transparent or opaque in response to human movement [8]. They propose that designers engage with 'becoming materials' through a combination of creative experimentation and the development of new 'terms and concepts' to explain the materials and people's experiences with them. Importantly, the focus is not only on the characteristics of the mutable material but equally on, "the continuous negotiation of the material expression directly or indirectly with the contextual factors in which it comes to be." [4]

Considering interactive dance systems as a kind of 'becoming material' – even those which have less tangible manifestations such as projected light – is useful, because it highlights their ability to change, potentially radically, over time. It also im-

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plies that an interactive system's 'ways of becoming' – how it changes and when – are an important part of the properties of that system. Finally, it suggests that examining the processes of 'negotiation' – the ways that people experience a material and seek to engage with and adapt it – is an important area of research. While technical change is ongoing and experiences/practices with materials are evolving, there are nevertheless patterns of experience and use which emerge [26]. We can document these and also reflect on the implications of particular practices for both design and practice. In the context of interactive systems for live performance, this helps us develop a critical language for discussing works and can suggest directions for further creative exploration and research [10, 18].

Designers and researchers have long been concerned with the recursive relationship between the emergent properties of technologies and the ways that users make use of them. Orlikowski [26] for example, argues for the use of a 'practice lens' to ensure that researchers "examine how people, as they interact with a technology in their ongoing practices, enact structures which shape their emergent and situated use of that technology" [26, p.404]. While these structures will never be completely stabilised, it is also not necessarily the case that every use of technology is completely unique and without precedent:

"While a practice lens recognizes that technology use is always situated and emergent, it does not imply that such use is completely unique. On the contrary, because regular use of the same technology tends to be recurrent, people tend to enact the same or similar technologiesin-practice over time. In this way, enacted technology structures become routine, taken for granted, and even institutionalized within certain circumstances. Such stabilization for now of technologies-in-practice allows researchers to seek bounded generalizations about the types of technologies-in-practice likely to be enacted by particular types of users with specific technologies in various contexts and times." [26, p.421]

During the collaboration with Stalker Theatre, we have consistently observed that the technologies have embedded within them scripts - literally in the form of computer code, but also inbuilt design attributes which afford certain activities and inhibit others [1]. In effect, these characteristics mean the technologies shape and influence the behaviour of the creative team in the same way that human participants do. Like the other participants, technologies must be enrolled in the project, convinced to contribute ideas, support others and be coached to perform reliably in rehearsal and performance. We argue that drawing distinctions between 'artists' and 'technologists' is unhelpful, and that characterising digital systems as passive 'technologies' which perform the creative intentions of artists (digital or otherwise) is oversimplified and misleading.

Actor-Network Theory is an approach to social theory that plots and examines the relationships between human and nonhuman stakeholders (Actors) to help document and understand complex situations [22, 21]. Following this theory, we argue that the digital systems are not passive and can instead be



(Photo: Matthew Syres, ©Stalker Theatre) Figure 1. Particles respond to performer movements in *Encoded*

seen as *participants* in a complex collaboration involving all manner of humans and non-humans. The advantage of this perspective is that it helps ensure that the artistic work is not seen as a human social construction with technologies merely playing a passive, subordinate role; or, conversely, as a technology-driven work in which humans solely play the roles allocated to them by designers. In short, it promotes a symmetrical view in which human and non-human actors are considered on equal terms. As such, in this paper we use Actor-Network Theory as a kind of 'lens' which helps us keep both human and non-human technological 'materials' in focus across the entire spectrum of collaboration.

PERFORMANCE WORKS

In this paper we document an ongoing collaboration between the authors, acting as interactive digital artists/researchers, and Stalker Theatre, a physical theatre company. Five major performance works have been created by this collaboration since 2011, with work already commencing on a sixth project to be completed in 2020.

The first work produced was *Encoded* (Figure 1), an abstract dance and physical theatre work which explored humankind's relationship with the space around them, from industrial times through to the future of digital and virtual environments. It was the first Stalker production which used interactive technology and it featured a mixture of interactive and pre-rendered visuals which were projected onto a large wall behind the performers. As the physical performers danced on stage and somersaulted across the rear wall on harnesses five metres into

the air, the interactive system would project particles floating on a virtual fluid simulation that would ebb and flow in response to their movements in real-time. The show also featured 'virtual costumes', a bespoke technology where mini projectors – attached to a wearable harness – projected imagery onto the body of the performers. A preview of *Encoded* can be viewed at http://vimeo.com/55150853.

The second production was *Pixel Mountain* (Figure 4), a crosscultural collaboration between the Australian based Stalker Theatre and South Korean performers and composers. This piece was inspired by the landscape of Seoul where digital billboards and high-rise apartments are surrounded by natural mountains. It employed similar technologies and techniques to *Encoded*, but this time the interactive imagery was projected was onto the side of buildings to create a theatrical event suitable for outdoor festivals. A preview of *Pixel Mountain* can be viewed at https://vimeo.com/76746676.

The third and fourth productions were two complementary performance works for children: a physical theatre show, Creature (Figure 3), and an interactive installation, Creature Interactions (Figure 5). Both were inspired by Ethel C. Pedley's classic Australian children's novel, Dot and the Kangaroo, in which a young girl becomes lost in the Australian bush. She befriends a mother kangaroo and, after eating some magical berries, the two share an extraordinary journey, during which the little girl talks to a number of native Australian animals and learns of humans' negative impact on the natural environment. Both the theatre show and the interactive installation explored the ecological themes and narrative of the novel and featured large-scale interactive visuals that responded to physical movement. A preview of Creature can be viewed at https://vimeo.com/199996091 and *Creature Interactions* can be viewed at https://vimeo.com/175791648.

The fifth show, *Frameshift* (Figure 6), was another Australian and South Korean collaboration which explored the past, present and future of South Korean life through physical performance and digital projections. The piece is designed for outdoor festivals and features three separate scaffold structures which act as both projection surfaces and physical theatre apparatus with projections, dance and acrobatics occurring from all sides of the large octagonal centrepiece. A preview of *Frameshift* can be viewed at https://vimeo.com/200447205.

OBSERVATIONAL METHODS

Ernest Edmonds argues for careful examination of users' experiences with interactive artworks to "develop a critical language" and "provide a framework that informs creative practice" [10]. To examine the user experiences across this diverse body of work, our consideration of the relationships between stakeholders and their practices is deliberately broad and draws on several sources of data. These include approximately 28 hours of interviews with the entire range of people involved in the development and production of the works, including the roles of a performer, director, choreographer, company manager, writer, composer, musician, production manager, lighting designer and digital artist. These semi-structured interviews were primarily conducted at the conclusion of productions and were recorded and transcribed for analysis. In addition to these

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(Photo: Darren Thomas, @Stalker Theatre) Figure 2. Physical movement reveals the digital scenery of *Creature*

interviews, the volunteers of the *Creature Interactions* installation were asked to fill out a short open-ended questionnaire of their experience.

As key participants in the projects, we were also able to draw directly on our experiences and reflections on the entire production process. To facilitate this, careful notes were kept during all stages of development and production, and many hours of video footage of the developing works were taken, along with photographs. Grounded theory was used to codify, memo and analyse the data with the 'constant comparative method' [13, 12] producing over 130 individual codes which were then sorted into coherent threads.

It is important to stress that that we do not claim that the findings presented here are generally applicable to all works of this kind. The research is qualitative and interpretive, our goal being to document and examine, as richly as possible, what went on during the development of these interactive theatre works which made intensive use of interactive technologies. The intention is to identify key creative and technical practices, terminology and relationships so that that others working in these broad areas can learn from our experiences in this developing area.

TRAJECTORIES

Trajectories describe the path of bodies through space and time in reaction to external forces. At the simplest and most direct level, they describe the path taken as the acrobats and dancers swing through the air on giant rope-like slings throughout these works. They also describe the resultant movement of digitally projected particles suspended in a virtual fluid simulation, as they 'float' across the stage in response to this physical movement. In other works, the term has been used to describe the shape and mutation of sounds moving through space in electroacoustic music [29], compositional paths existing in interactive sound design [15] and the compositional ebb and flow of timbre, texture and density within the musical compositions [32]. Edmonds and Candy [11] use the term trajectory to describe the changing relationships between research and artistic practice common in practice-based research while Benford et al [3] observe the trajectories of participants as they traverse immersive artworks in multiple physical locations.

In this paper we interpret the concept of 'trajectory' broadly to describe the way the conceptions, interactions and implications of interactive systems have changed over time as they are 'becoming material', and to identify the influences (or forces) which continue to shape, but not define, these traits as the collaboration continues to evolve. In the following sections we identify and describe numerous trajectories that have been observed during this collaboration, categorising them as:-

- **Intra-production trajectories** which map the evolution of a trait through the entire development of a single production, and
- **Trans-production trajectories** which describe the evolution of a trait over the period of an entire body of work, across multiple productions.

INTRA-PRODUCTION TRAJECTORIES

These trajectories describe the processes by which the works are developed from initial inception to a fully realised and tourable production. The intra-production trajectories we identified describe shifts in the way performers interacted with the technology during show development, and how the technology was refined to ensure robustness and reliability.

Interaction from contact improvisation to choreography

In the early developmental stages of *Encoded*, a series of workshops were held where the performers experimented with interactive sketches prepared by the digital artists. At this stage, interactions were largely improvised, often playful and focused on sensing the relationship and mutual influence of movement and projections. During these play sessions, the digital artists would often be tweaking the parameters that influenced the interactive system as dancers improvised.

One performer likened these early, playful interactions to contact improvisation:

"Yeah well it's a duet isn't it? Like a form of dance that I do is called contact improvisation. It's a partnering dance form that is also improvised and you're in contact with another person but through that point of contact there's an immense listening... So it becomes a dance of one but with two bodies without verbal communication. So I think, you know, the interactive systems are that. It's just finding the listening point between the projections or the music and the person playing [them]..." (Performer)

The metaphor of contact improvisation (CI) [27, 30] is an intriguing one for digital artists working in performance contexts. In CI, performers use physical contact as a starting point for movement improvisation. Generally, performers stay in physical contact during performance and communicate through touch as the improvisation develops.

In this case the situation is further complicated by the fact that interactive systems are in the mix. Thus, there is 'contact' between the performer and the interactive system via the cameras and simulations employed by the interactive system, and further contact between the digital artist and the system as they tweak simulation parameters, visual settings, etc. Finally, the performer and digital artist are also in contact *through* the

interactive system, which acts as a kind of mediating material with its own characteristics.

CI is often used as a starting point to encourage exploration prior to creating set choreography. While it was not consciously employed in any of the productions, early workshops nonetheless contained a strong component of improvisation and experimentation. This improvisation helped sensitise the performers, digital artists and interactive system to one another and facilitated the emergence of a palette of movements and interactive states which was drawn on to create the final work.

This development style is based loosely on a process called 'devised theatre' [25]. A devised theatre work, "originates with the group while making the performance, rather than starting from a play text that someone else has written to be interpreted." [25, p.1] It has also been a way to bring technical innovation to theatre: "In devised theatre, technical areas of expertise can contribute to the making process, developing with the product in its evolution." [25] p.18.

For *Encoded* the trajectory of development began with improvisations in a series of workshops. From these improvisations the director identified the more effective interactive, visual and choreographic moments. In a process reminiscent of that described by Stevens et al [31], these moments formed the 'palette' from which the director could select and rearrange to create the final work.

Of particular interest from an interaction design perspective was that the performers describe a reduction in their interaction with the system as the show developed. The interactive focus tended to shift towards the other human performers and away from the interactive technology. The technology was increasingly trusted to respond effectively as development progressed, but was not considered to 'talk back' to the same degree as it did in earlier, more improvisatory phases. At this stage the interaction between human performers focused on nuances of movements and timing as the core elements of the choreography were now in place. However, perhaps due partially to the difficulty in physically seeing the projections while performing, in lights, on stage [19], the visual feedback from the interactive systems was not given the same level of attention.

Asked whether they felt the same sense of contact improvisation between interactive system and performer in the final performances of *Encoded*, one performer responded:

"No not at all. I think because I was so focused on doing the movements that had been set it never kind of really got there. And...most of the scenes that I was in were also with another dancer... so my first point of connection was with that person and then the projection if I got there... So it was making sure I was in time or connected with the person, and then maybe by the end I was starting to see the projections, but [I] don't feel like I really got there in the end." (Performer)

The journey from contact improvisation to choreography shows how the interactive system itself followed a similar trajectory to that of the performers themselves in this devised theatre context. In collaboration with the interactive designer, the system initially played the role of improvisational dance partner with the human performers, simultaneously shaping and being shaped by the material of the spontaneous choreography. As the show developed, the choreographic and interactive material that was moulded through improvisation was set and the palette of interactive aesthetics was locked down. The interactive system had become one of the choreographed elements of the production.

From prototype to production

As the interactions and movements of the performers shifted from being improvised to choreographed, the technology followed its own trajectory throughout the development of Encoded. The interactive projection system went through a series of refinements to ensure it was sufficiently robust for reliable live performance. The early prototypes of the system used multiple Kinect cameras for markerless skeletal tracking of the performers. The Kinect system facilitated the building of aesthetics and trialling of ideas in an improvisational fashion during workshops but a public demonstration highlighted the kinect's inadequacies in the face of a live performance. The tracking worked best on a standing position and struggled to track the performers as they acrobatically somersaulted along the ground and swung on trapeze like ropes (or slings) high in the air. The constant need for performers to assume the half-squatted T pose in order to re-calibrate the kinect camera system seriously affected the artistry and flow of the demonstration performance. A simpler and more robust tracking system was eventually developed using an infrared camera and the OpenCV optical flow algorithm, allowing any type of movement on stage to be tracked. This tracking system was very successful in the Encoded performance and has subsequently been used in all of Stalker's productions since.

The virtual costume technology went through a similar trajectory to increase robustness during the development of *Encoded*. Each costume consisted of a bespoke aluminum harness worn by the performers with three miniature projectors aimed at their bodies and face, displaying video from iPod Touches hidden at the back of the harness. A number of upgrades were made to the battery-packs, harness structure and video playback software to increase the running time and facilitate a remote and synchronous switching of video projection to fit the live dramaturgy of the performance.

Just as human performers hone and refine their physique and skillsets based on the demands of an individual performance, the technological systems need upgrading and refinement to meet the demands of live performance and the rigour of extensive touring.

VARIATIONS AND INFLUENCES

The five major productions of the collaboration all followed the same general intra-production trajectories as described above. When comparing the works side-by-side, however, we can see that certain production-specific forces can influence the exact shape of these trajectories. The dynamics between interaction and dramaturgy and the way that artists perceive

the interactive systems were observed to subtly shift between these productions.

Interaction and dramaturgy

When comparing the development of *Encoded* to that of *Creature* (the theatre show), we can see a similar trajectory of development but with some important differences:

- There was a narrative story to be told and, consequently, a script. The script was, however, not fully completed in advance of the final month of show development and, as such, could incorporate other elements of the palette as they emerged and were refined.
- The technical systems had built on the foundations of previous systems, growing in scale and capability.
- There was greater use of animated scenery which was created prior to the final show development workshop.
- The work was targeted at children and had a more literal aesthetic style.

We observe that, although following a similar trajectory, the focus of each development was different for each production. For the more abstract, adult work, *Encoded*, the shape and mood of scenes (dramaturgy) would tend to be adapted to make use of the palette of interactive states. *Creature* was a theatrical retelling of a children's novel, and it was more common for the palette to be adapted to fit the story. For *Creature Interactions*, the guided activities which took place in the workshops were largely devised to shape the energy and flow of participatory interaction in response to the previously created interactive states. *Frameshift* and *Pixel Mountain* adapted the interactive palettes and choreography to fit the architecture of the buildings that they were performed on in a bid to highlight and transform these physical spaces with simple optical illusion and projection mapping.

This shift of focus suggests that the technology has been used in different ways in each of the productions. The exact role that the interactive system plays within these productions is shaped by the style or genre of the performance artwork.

Conceptions of the interactive system

When interviewed in 2016, the different team members of *Creature* saw the interactive projections as fulfilling different roles in the production, with some describing multiple roles that shifted throughout the entire interview.

There was a perception that the interactive system was almost like having another *character* on stage to interact with (see Figure 3).

"it's almost like another character I guess on stage. So you can't not interact." (Performer)

Many of the crew saw the visuals, particularly the rendered bush landscapes as an animated backdrop or digital set that would merely describe the location for the live action.

"I mean this in the nicest possible way, it was like a digital set." (Sound Designer)



Figure 3. Particles are treated like a character in *Creature*

Despite being run from the same system and displayed on the same screen surface, the Costume Designer viewed the bush landscapes and the interactive particles as being two separate layers with different depth qualities. She simultaneously describes the projected imagery as a *digital set* and a source of *lighting*. This view reflects her professional relationship with these two mediums, ensuring the costumes aesthetically match the set design whilst also being concerned with the quality of reflected light that results from choices in costume materials.

"unquestionably light was the set in that work. In all it's different, or the 3 major categories of it....[landscape] animations, and the interactive work and then the lighting. And it's a classic thing that lighting designers sculpt with light, so in the work we have 3 light sculptures happening" (Costume Designer)

The artistic director relates to the technology through the concept of a *mask* which has been traditionally used in theatre practice to anonymise and/or influence the movement and presence of an actor. The framing of a mask allows him to see the technology as being a kind of actor/set hybrid, which has its own presence that is both influencing and being influenced by the actors at the same time.

"It's almost like if you put on a mask, there is a different type of presence that you use as an actor. As a director what I perceive when we have the interactive technology, alive, is again there is a type of presence being manifested on stage and that presence is almost like another actor but not quite. Is it a mask? In a mask sense you are possessed by the mask. But it's a diffuse mask that is affecting all of the space... we are creating a living, a kind of living, breathing set, and that is the difference." (Artistic Director)

In the 2012 interviews, Johnston found that the cast and crew of Encoded also viewed the interactive system in a number of different ways including a contact improvisation dance partner, a movement amplifier and an interactive theatrical *mask* [19]. While the system is seen in a number of roles in both productions, the type of roles has changed. The visuals used in the 2012 physical theatre piece (see Figure 1) are described as a way to change the *movement* of the dancers either through contact improvisation, movement amplification or masking. The Creature projections are described through traditional theatrical storytelling elements of a character, set, or lighting design. Even when viewing the technology as a mask in both productions, the Director mentions the 'movement of the body' when describing this effect in Encoded and 'actors', 'presence' and 'sets' when describing it for Creature. The conceptions of the technology shifted from being movement or dance based (see Figure 1) to being one of storytelling (see Figure 3).

Encoded demonstrated how both human performer and interactive system can influence each other through Contact Improvisation. By using an Actor-Network Theory perspective to view human performers, interactive systems, inanimate objects and pre-made scripts on equal footing we can observe factors that have influenced the trajectory of each production. In addition to the immediate response of system to performer movements, the interactive aesthetic and role of the system has been influenced by (and influenced) the audience demographic, physical architecture, dramaturgy and narrative journey particular to each production.

TRANS-PRODUCTION TRAJECTORIES

Trans-production trajectories describe the path of a trait that spans the entire body of work, evolving across multiple productions. These trajectories include an expansion of the visual and interactive palettes, the evolution or decay of technological robustness and the expansion of each production beyond the conventions of the theatrical stage.

The evolution of technical aesthetics

The software system used for both the theatre show and the interactive installation is an evolution of the fluid based particle system developed for the initial 2012 work, *Encoded*. An infrared camera and optical flow algorithm is used to process any movement in front of the projection screen and apply appropriate forces to a virtual fluid simulation. As the performers or participants move about the stage, they effectively 'stir' the virtual fluid which ripples and flows in response to this physical movement, carrying with it a mass of digital particles.

While the core of this interactive system remained unchanged for *Pixel Mountain* (see Figure 4), a substantial series of technical upgrades were added to create a large 360° interactive playspace for *Creature Interactions* and expand the visual palette for children's storytelling in *Creature* the theatre show. An attraction system was implemented where particles could loosely stick to the vertices of 3D models, allowing simple images to 'emerge' from the abstract particle system. Bullet¹, a



Figure 4. Pixel Mountain features monochromatic dots and lines

rigid-body collision simulation, was added to the system allowing 3D particles to semi-realistically bump, rub and spin when in contact with one another. The particles can be attracted or repelled from the source of physical movement and, when combined with the collision simulation, this effect strongly resembles a flocking algorithm. A range of real-time visual effects (such as blurs, trails, masking and lighting) were added and a layered compositing engine was built to combine the interactive particle graphics with pre-rendered video and visual effects in real-time (see Figure 2). A network architecture and projection stitching capability was added to enable combinations of multiple cameras and projectors in a unified 360° display. These upgrades enabled the landscapes and characters to be portrayed with a diverse interaction style and more literal visual aesthetic in Creature [6] and facilitated an immersive 360° presentation of Creature Interactions [5]. The development of the interactive system was shaped by the needs of each individual production, and with each new addition the visuals and interaction palettes became increasingly sophisticated. Over multiple productions, the system has shown a steady trajectory of expanding and building on the foundational material created for the original Encoded performance.

Development and decay

The interactive system and virtual costumes shared a similar intra-production trajectory from prototype to performance-

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worthy technology during the development of *Encoded*, but exhibited very different trajectories when viewed over the entire body of work. The interactive system was constantly refined with each new production, using the information gathered from touring the system in a host of different locations and operating environments. An automatic adjustment of lighting levels was added to combat the inconsistent conditions of outdoor festivals, such as when street and car lights are switched on and off throughout a performance. A storminduced power outage during one performance prompted the addition of an auto-save feature to minimise the requirement for lengthy camera calibrations when confronting similar disasters. The technology used to composite the pre-rendered graphics with the interactive motion-tracked visuals evolved to the extent where the pre-rendered visuals were run from within the interactive software system on one computer. This removed the need for multiple computers to be connected through the often temperamental live video capture hardware.

The interactive projection system followed a trajectory from the cutting edge, but difficult to manage, technology in *Encoded* to the almost plug 'n' play operation in the *Creature* performance four years later. Just as this technology had become robust and manageable, it was extended to incorporate multiple cameras, rendering computers and projectors to surround the audience with a seamless 360 degree interactive projection environment in *Creature Interactions*. This extension of the technology once again placed it into the category of cutting-edge, where although functional, it teeters on the precipice of malfunction.

"All this stuff it's solid now. It's not going to fail. The cameras going to pick up and the lighting and all that, but at the cutting edge of your investigation there, it's all uncertain, you know." (Virtual Costume Designer, talking about the evolution of the interactive system in *Creature* and *Creature Interactions*)

In contrast to the evolution of the interactive system, the virtual costumes have followed a less fortuitous trajectory; one of digital decay. Although a successful part of the Encoded performance, the virtual costumes restricted the movement of the performers and needed intricate fitting and management during each performance. They were subsequently replaced by a simpler LED costume for *Pixel Mountain* and, following similar issues with the replacement costumes, the notion of a virtual costume was dropped from later productions altogether. In contrast to the interactive projection system, the virtual costumes did not evolve or increase in robustness with each show and subsequently suffered a form of decay over the touring life of Encoded. The projectors and iPod Touches mounted to the costumes wore out through constant use and suitable replacements were difficult to find. The iOS operating system has evolved considerably since the premiere of the show, such that newer model iPods no longer run the bespoke software app made for the costumes. Sourcing older devices that can still run the outdated software became a serious issue 3 years into the tour and could well become impossible if touring of Encoded persists for much longer. In an age where technology is being constantly updated and outdated, bespoke

technologies will inevitably face the dilemma to update or perish.

"I hate seeing [performer] wearing that thing. He's rude with them. They're fragile, they're really delicate devices." (Virtual Costume Designer, talking about the *Encoded* virtual costumes)

As with many organic construction materials, without constant maintenance the virtual costumes become brittle and begin to decay. This decay has a knock-on effect where as it is used less often, it becomes less maintained which further compounds the problem. Materials that are in constant use will often be better maintained and may therefore enjoy a longer life-span.

Reduction of prototypes and workshops

The individual stages of the developmental trajectory from think-tanks and workshops through to final development and touring were clearly demonstrated in our first collaboration, *Encoded.* While each subsequent production has followed this general trajectory, certain stages have become less prominent as the interdisciplinary practices and technologies have become more familiar to the team.

Pixel Mountain, involving many of the same performers and artists as *Encoded*, reused the technology and interactive palette developed for the earlier work and therefore skipped the prototyping, workshop and demonstrations stages altogether. Creature the theatre show and Creature Interactions were conceived simultaneously and the early development of these productions were suitably intertwined. The ideas for the characters and locations for the installation came from a think tank primarily focused on the theatre show, while the technology and visual aesthetics used in the show were derived from an intensive workshop focused on creating the interactive installation. Similar to Pixel Mountain's development, *Frameshift* refocused the technologies and interactive palettes developed during the entire body of previous works to portray its narrative of Korean culture and skip the early developmental workshop and prototyping stages. This pattern suggests that, while all of these stages of development are important to each production, artists can draw on the experience, technology and aesthetics developed in previous works to shorten the trajectory of development to a certain extent.

Beyond the proscenium

The *Encoded* performance was an ambitious embarkation into interactive digital projection and mixed reality theatre for a small physical theatre company. While the integration of physical movement with interactive visuals was a significantly novel proposition for all involved, the show itself remains a relatively standard proscenium arch theatre show. Technically it requires a single projector, infrared camera, two laptops, three virtual costumes and a fairly modest theatrical lighting system found in many small to medium theatre spaces. *Pixel Mountain* and *Creature* share similar technical requirements, although they require a slightly better quality of projector than *Encoded*. This is largely because *Pixel Mountain* is performed outdoors on large buildings and *Creature* features detailed colour images which benefit from a dedicated projection screen and quality projector. While there has been a slight trajectory towards a



(Photo: Darren Thomas, ©Stalker Theatre) Figure 5. Creature Interactions in a 360° immersive environment



(Photo: Alejandro Rolandi, ©Stalker Theatre)

Figure 6. Performing on bespoke scaffolding structures in *Frameshift*

more expensive projection setup throughout these three works, they still remain within the facilities and budgets of a standard proscenium theatre show.

Pushing the interactive mixed reality boundaries beyond these standard setups may increase the spectacle of a show but can make them difficult to tour. *Frameshift* is an outdoor theatre show which is performed on three separate 10 metre high purpose-built structures, and uses up to eight projectors, three cameras and four computers to realise the interactive projections on all sides of the giant structures (see Figure 6). Not only are the structures and projectors expensive, but a large open space is needed to present the work. The three giant structures need to be installed with suitable room for the performers to fly around the outside on a rope system, whilst still providing suitable space for a large audience to have a quality vantage point and locations from which to unobstructedly project around all three structures.

Creature Interactions is a very different work for Stalker that hybridises a participatory interactive art installation with a theatrical performance. It requires a large 20m x 15m empty room with four walls that can be projected onto to create an immersive 360 degree environment (see Figure 5). Technically

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it uses six projectors, six cameras and up to eight computers to drive the system and features a live actor and three or four facilitators to guide the interactive experience for up to 90 children. It is also capable of being presented in stereoscopic 3D which further requires active shutter glasses for the entire audience. While the installation can be run as an independent piece, it was designed to be presented alongside the Creature theatre show as it explores the same graphics, characters and themes. There has been considerable interest in touring the work, but Australian theatres are struggling to find spaces suitable to house the installation. Conversely, museums are interested in housing the work long term, but struggle to deal with the logistics of live performers. The novel hybrid of interactive installation, immersive visuals and live performance has piqued the interest of producers and show-presenters but is sufficiently outside of traditional theatre and museum oriented interactive art practice that there appears to be a deficiency in suitable venues.

The collaborations have shown a trajectory towards more ambitious technologies and stage setups, pushing the works outside of traditional proscenium arch theatre venues. While there has been an increase in the complexity of presenting these works, the trajectory to include more digital elements has, somewhat erroneously, given presenters the idea that these works are cheaper to perform than traditional live theatre.

"The difficulty we're finding with it is actually I think there's a perception that because it's digital that it's cheap." (Stalker General Manager)

In addition to the costs incurred developing the bespoke software for the system, creating digital assets (3D models and sounds) and crafting the interactive experience of Creature Interactions, there are still considerable costs involved in installing and running the work. The bespoke system involving multiple projectors, cameras and computers requires dedicated technicians to install and calibrate the system for each unique venue. This installation process may make the work prohibitively expensive for one-off small to medium sized events. Where an installation is to be run for a period of time (say in a gallery or museum), the continual expense of having live performers for extended periods of time may be outside of their normal running costs. In either case, this cost does not exceed that of a traditional live performance or artistic experience of a similar scale. The educational advisor for Creature Interactions posits that as the works continue their trajectory beyond a standard theatrical setup, producers will need to understand that the large digital component to the work is an aesthetic or artistic choice, and should not be viewed as cost-cutting exercise.

"You can't see technology as a babysitter, as a cheap way to kind of make money, you know. It needs as much care and as much curation as does any work in the arts." (Creature Interactions Educational Advisor)

The ability for the interactive system to evolve and morph over the length of the collaboration has pushed the theatre company into increasingly bespoke stage designs and performance dynamics. The bespoke nature creates an appealing

point of difference from the traditional proscenium presentation, but this divergence creates budgetary and logistical pressures when operating within the existing structures of the performing arts industry.

Planning for a hybrid future

To overcome the difficulty of finding a physical and budgetary home within traditional theatre and gallery institutions, the company is seeking to create their own niche by building their technology into a large and portable geodesic dome. This will hopefully alleviate many of the problems associated with finding suitable locations such as lack of space, poor lighting conditions, lack of mounting points for physical performance equipment and low quality projection surfaces. The dome itself can be weatherproofed for outdoor events, with grassland reserves, sporting grounds, car-parks, and empty warehouses becoming makeshift theatrical performance venues thus expanding the potential for regional touring. The cost of performing a show can also be controlled and well known in advance as the setup, performance and equipment would be identical for every performance. Artistically, knowing the exact form of the performance venue can open opportunities to engage with the space in a unique way, especially given the unique format of a geodesic projection dome.

Portable dome structures have previously been used to provide immersive educational content [14] to schools and regional areas and the circus has a long history of performance in touring big top structures. Combining immersive digital content with advanced aerial performance and audience interaction in the one portable dome appears to be ideal, but there are many conflicts still to be resolved. These include maintaining a stable and steady infrastructure for the ceiling-mounted projectors and tracking cameras all while performers wildly swing to and fro from the dome rigging. Similarly, clear sight lines for the projectors will be difficult with performers swinging in the centre of the space and the audience free to roam and interact with the outer walls of the space. These concerns will need considerable engineering and infrastructure design to overcome. While providing significant challenges, the unique shape of the dome also creates unique staging and audience placement opportunities where the audience can be inside, outside, or below the performance arena. In order to allow for physical performance, immersive 3D visuals and audience interaction to coexist in a shared dome space it may become desirable (or indeed necessary) to reconfigure the physical orientation of the audience according to the needs of each production or individual scene, providing yet another trajectory to explore in the future performances.

CONCLUSION

Within this paper we have argued that the technology in interactive productions cannot be viewed as a fixed constant, but rather a malleable 'material' which evolves and changes over time. We have shown Actor-Network Theory to be a useful lens through which to view these collaborative works and demonstrated that many non-human factors can influence the evolution, use and perception of an interactive system over time. These factors include staging design, choreography, budgeting, narrative style and performance genre which can all alter the development of technology and are in-turn impacted by the technical capabilities and aesthetics of the system itself.

We have identified several trajectories that have occurred across a body of five major interactive theatre works and several years of collaboration, including:-

- **Intra-production trajectories** which mapped the development from idea conception and prototyping through to final production. As the technology becomes more robust and the production moves towards a final development period, the interaction with the system has shifted from free improvisation to a more formalised choreography.
- Variations and influences in these trajectories were observed across productions where the focus has shaped the relationship between dramaturgy and interaction aesthetics and changed the way that performers access and conceive of the technology.
- **Trans-production trajectories** which describe the evolution of a trait over the period of an entire body of work, across the span of multiple productions. The interactive system was increasingly upgraded with respect to visual and interactive aesthetics and a trend towards increasing robustness was identified. As the technological components increase and the boundaries between interaction (including audience participation) and theatrical performance continue to blur, the company is becoming more invested in the presentation of works outside of traditional theatre venues, including the push to work inside a controllable dome structure.

These trajectories describe a continual change over the span of the collaboration and highlight a wide range of influences to the development and use of the interactive system. The diversity of interaction styles, staging designs and performance genres used throughout this lengthy collaboration demonstrates the malleability of the interactive system as it evolves over time. We hope that by identifying and articulating the trajectories identified in this paper we will help those working in this area understand the relationships between technology, design and creative practices and motivate further exploration.

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