Immersion and Interaction: Creating Virtual 3d Worlds for Stage Performances

A thesis submitted for the degree of Doctor of Philosophy

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Abstract

This thesis formulates an approach towards the creation of a gesture activated and body movement controlled real time virtual 3d world in a dance performance context. It investigates immersion and navigation techniques derived from modern video games and methodologies and proposes how they can be used to further involve a performer into a virtual space as well as simultaneously offer a stimulating visual spectacle for an audience. The argument presented develops through practice-based methodology and artistic production strategies in interdisciplinary and collaborative contexts.

Two choreographic performance/installations are used as cases studies to demonstrate in practice the proposed methodologies. First, the interactive dance work *Suna No Onna*, created in collaboration with Birringer/Danjoux and the Dap Lab, investigates the use of interactive pre-rendered animations in a real time setting and in real time by incorporating wearable sensors in the performance. Secondly, the potentials offered by the sensor technology and real time rendering engines led to the “creation scene", a key scene in the choreographic installation *UKIYO (Moveable Worlds)*.

This thesis investigates the design, creation and interaction qualities of virtual 3d spaces by exploring the potentialities offered by a shared space, between an intelligent space and a dancer in a hybrid world. The methodology applied uses as a theoretical base the phenomenological approach of Merleau-Ponty and Mark Hansen’s mixed reality paradigm proposing the concept of the “space schema", a system which replicates and embeds proprioception, perception and motility into the space fabric offering a world which “lives”, functions and interacts with the performer.

The outcome of the research is the generation of an interactive, non-linear, randomized 3d virtual space that collaborates with a technologically embedded performer in creating a 3d world which evolves and transforms, driven by the performer’s intention and agency. This research contributes to the field of interactive performance art by making transparent the methodology, the instruments and the code used, in a non-technical terminology, making it accessible for both team members with less technological expertise as well as artists aspiring to engage interactive 3d media promoting further experimentation and conceptual discussions.

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Introduction

Art and technology have always worked together. From “Deus Ex Machina” of the ancient Greeks to the revolving stages of the Kabuki dance in the 17th century, technology was always used to enhance the experience of the performing arts. Multimedia performances began as early as the start of the 20th century – Winsor McCay projected animated films in his vaudeville performances in 1911 and Karel Capek used motion projection as a purely scenic element in his 1921 play R.U.R.; Erwin Piscator who opened his own theatre with seven or eight acting areas and surfaces for film and slide projections as well as the Czech director Josef Svoboda were some of the first theatre directors who were attracted to the new medium of film (Goldberg 1979, p. 75). The roots of contemporary motion capture can be traced from even before by looking at chronophotography, a photographic technique which captures movement in several frames and subsequently displays successive phases of motion (pioneered by Muybridge in 1867-68).

With the experimentations of the early 20th century avant-gardes and the multi-disciplinary, participatory events of the 1960s projected film and then video gained popularity in performance art, dance and visual arts contexts. A number of artists, such as the Korean born Nam June Paik combined video, live music and performance creating mixed media hybrid art works. Furthermore, video dance and dance-on-film have been used by performers and choreographers since the 1980s, along with video documentation for analyzing choreographies.

The development of electronic arts and the interest in related fields such as film, electronic music, digital entertainment, telecommunications, design, robotics and the internet sparked an interest for both performance theorists and practitioners towards the computational and processing capabilities of the computer and the potential integration with their practice. This leads not only to new conceptual and compositional ideas but also to new instruments and technologies such as cameras, sensors, microphones, computer software and more recently wireless technology, easy to assemble micro-controllers, affordable VR equipment, smartphones and tablets. Interactivity, used here in the context of the process of acquiring gestural or body movement data from a performer or a user through the means of technological mediation and subsequently using it to activate or control a digital system with-in a shared real time environment, was a natural fit with the “happenings” movement since it implied the active participation of the users, a much sought out concept at the time.

Since then, interactivity in art has been commonly used in installations as well as dance and theatre performances, often referred to as digital performances, and has also provoked long debates about its value amongst theorists. Even though the term digital performance as yet lacks any universal definition, the word digital encompasses techniques of encoding data such as movement, video, 3d graphics and music in a way that allows communication, manipulation and interpretation. It denotes computational and/or parametric processes and the addition of a human-machine interface structure suggests the design of a real time interactive system.

My aim in this thesis is to investigate the evolution of the digital technologies, concentrating on the design, creation, as well as the interaction qualities of virtual 3d spaces, when viewed from a dance performance context. I will explore concepts from a number of theorists, including Mark Hansen, Lev Manovich, Maurice Merleau-Ponty, Myron Krueger, Ilya Kabakov and Johannes Birringer as well as analyze works from renowned artists and groups like Stelarc, Char Davies, OpenEnded Group, Trisha Brown Dance Company, Chunky Move and Tamas Waliczky. Furthermore, I will carefully look at immersion and navigation methodologies and techniques derived from modern video games and propose how they can be used to enhance the experiences offered by a projected virtual space in a stage performance. I will then formulate and propose a specific theoretical framework for creating an interactional 3d virtual space using as a base Merleau-Ponty's phenomenological approach and Mark Hansen's mixed reality paradigm. At the core of my thesis lies the construction of performative interface designs enabling dancers or actors to create virtual 3d worlds in stage performances or audio-visual installation performances.

When I began my research for this thesis and my creative concepts for interactional design, there were no appropriate software tools to assist me in the creation of the virtual world. I therefore needed to create my own platform utilizing wearable sensor technology, a camera vision system and a modern game engine, in the pursuit of creating and projecting a gesture and body movement controlled 3d space. As part of the initiative to contribute to the dance and technology community, I then posted the open source code to the public domain, allowing anyone who wishes to use or expand it. Unlike commercial software sold to the end user which is supplied in a compiled ready-to-run version, open source software relies on self-created communities of individuals who come together and do collaborate work on their selected platforms, by exchanging ideas, methodologies and code snippets.

In the technology section at the end of chapter 4 I break down the code and explain in simple terms how each code snippet works so that the reader gains a full understanding of the technical processes and discoveries involved in the research. As a member of the DAP Lab and its ensemble, which had been formed by Prof Johannes Birringer in 2004, I proceeded to put in practice both my theory and the technological processes in two interactive dance performances (*Suna no Onna* and *UKIYO - Moveable worlds*) which were produced in 2007-8 and 2009-10. I had joined the Lab team in 2007 when the initial research rehearsals for *Suna no Onna* started to get under way. A different approach was taken for each performance, and in chapters 5 and 6 I will break down, explain, analyze and evaluate these approaches in the context of each of the performances which serve as my core case studies.

Investigating digital performance culture needs to be done in close relation to a consideration of the technological imagination which acts as its main drive. Birringer in his paper "Performance and Technology" reminds us that "the question of what is groundbreaking in the coupling of dance and technology needs to be examined carefully in order to make any claims for a new art form or a successful marriage of dance and interactive image." He then goes on to point out the importance of treating digital performances as a new medium and argues that "…if we look for artistically challenging dance content created by emerging interactional choreography, a medium specific analysis requires an examination of choreography, spatial design, dancing, technologies and dance-technologies in their own particular interactional, digital manifestations" (Birringer 2007, p. 84). These issues are subsequently explored by Birringer and the DAP lab, along with the equally important and much debated issue of technological embodiment which has exercised numerous contemporary writers and critics. Older games and virtual reality projects aimed to isolate a disembodied subject in a 3d space epitomizing the idea of the Cartesian dualism, a notion attributed to the 17th century French philosopher René Descartes. The philosopher suggested that the material body is purely mechanical and even though it is responsible for the perception of the senses, their awareness however lies in a separate immaterial entity called the mind (or the soul). Therefore, if the body and the mind are two separate entities, one could assume that it would be possible for the body to be left behind and through technological mediation transfer the mind to a new virtual or physical construct.

Describing her installation *Osmose,* Char Davies suggests that her main motivator was "a desire to heal the Cartesian split between mind and body, subject and object" (Davies 1995, p. 1). By making the user interface intimately and intuitively body-centered, based on physical balance and breathing, she seeks to re-affirm the physical body and its sensorial perceptions in a different realm. The performance artist Stelarc, constantly challenging the boundaries of his human body, did experimentations with prosthetic augmentation. He considers the body "biologically inadequate," and with a series of projects he has demonstrated how technology can be attached and work together with the body (*Third Hand*), how technology can be inserted into the stomach turning the body into a hollow host of a sculpture (*Stomach Sculpture*) and how technology can extend the human body in conjunction with an intelligent six-legged, pneumatically powered walking machine (*Exoskeleton*) actuated by the performer (Stelarc 2011).

Steve Dixon in his essay "The Digital Double" talks about various forms of digital manifestations of one's self. Doppelgangers that might appear in the form of particle streams, polygonal avatars, robotic dolls or just simple mirror images parade in contemporary performances often invoking the Freudian notion of the uncanny. Dixon calls the digital double "a mysterious figure which takes forms and undertakes different functions within a digital performance" and has identified four categories with distinct representations and themes. "(1) The reflection double announces the emergence of the self-reflexive, technologised self, conceived as becoming increasingly indistinguishable from its human counterpart. (2) The alter-ego double is the dark doppelganger representing the Id, split consciousness and the schizophrenic self. (3) The double as a spiritual emanation symbolizes a mystical conception of the virtual body, performing a projection of the transcendent self or the soul. (4) The manipulable mannequin, the most common of all computer doubles, plays myriad dramatic roles: as a conceptual template, as a replacement body, and as the body of a synthetic being" (Dixon 2007, p. 268).

While Dixon sees the digital double as a representation of an agent which lives in its own realm and is inherently doomed to eternally respond to stimulations, Hansen proposes an alternative form of embodiment. His mixed reality paradigm assumes that both the digital double as well as the physical agent can interact with each other's realms through the means of technological embodiment. Building up from Merleau-Ponty's notion of the phenomenal body, he proposes that embodiment can only be realized through an excess of the motile body schema and not trough the visual body image, giving therefore more attention to physical movement and senses beyond vision (Hansen 2006).

Cyberspace and the body

In the first part of chapter 1 I shall explore the theme of disembodiment by making an investigation of current technologies and technological trends. Commonly addressed throughout the ages by mythologists, shamans, and theologists, the idea of leaving behind the physical body is not something new. The *yaskomo* of the Waiwai, an Amazonian tribe, is believed to be able to perform a "soul flight" that can serve functions such as healing or consultation with cosmological beings (Fock 1963). In Japanese mythology an *ikiryo*, a manifestation of the soul of a living person, is said to leave the body in order to curse or harm another person they have a significant grudge against (Clarke 1999). Technological embodiment has carried the notion into the new age with films like *The Matrix* or *Avatar*, authors like William Gibson and TV series like *Caprica* portraying persons "jacked into a custom cyberspace deck that project their disembodied consciousness in the consensual hallucination that was the matrix", to use a phrase from his novel *Neuromancer*. By investigating the technologies aiming to tackle this escaping trope, I am trying to explore the possibilities of creatively implementing them into digital art. I have decided to start the main part of the thesis with a vision of future untested technological possibilities as I am a firm believer that digital art needs to work together with technology by preemptively embracing the direction it is headed rather than just waiting and using whatever becomes available.

The second part of this chapter, investigates a number of performances that use current technology to immerse the performers, the audience or even digital manifestations. My aim here is to introduce ideas on how technology is used to drive a concept in a variety of computational worlds evaluating the three different forms of immersion that can be created for the actors and/or the audience.

Until technology is advanced enough to create a fully 3d immersion holographic space, displaying a virtual 3d space is unfortunately limited to projecting two dimensional image streams. In order for the audience to experience a 3d world from more than one static camera viewpoint, a virtual camera needs to be navigated inside the Cartesian space. In the chapter on “Navigation” I examine the evolution of three dimensional representations by starting from a few important historical examples of navigational spaces in a number of art works and computer games, followed by an evaluation of common camera structures in a number of different game genres.

As the rise of 3d technologies has created the general misconception that we are getting closer to the desired notion of the Cartesian split; a number of games have introduced the “nameless” hero, the character we find in *Doom* that was meant to be controlled by a disembodied user. As the notion started dying out, we see the development of more complete characters and a shift of attention towards narrative, character interaction and emotional attachment through a number of techniques explored in the next section of the chapter. Furthermore, this chapter explores the work of two well-known artists, firstly Tamas Waliczky whose surreal and fascinating camera work serves as an inspiration for unconventional projected spatial representation; and secondly Ilya Kabakov, a master in designing installations which intensify our sensory awareness between the physical site, the images, the sounds, the memories and the experience.

Hansen’s mixed reality theory will be analyzed in chapter 3 as well as serve as a theoretical basis for my framework of interactional 3d space. Moving past Dixon’s digital mirror image manifestations and commonly used particle effects, this thesis envisions a three dimensional space linked to the physical body of the performer through technological mediation. The virtual realm becomes a place of possibilities as conscious and unconscious movements turn into raw data, travel through cables and wireless technologies, enter local or network servers, get arranged into lists and pass through filters allowing the data to flow into the virtual structures that make up the 3d space. There, the data is passed through a series of computational processes and working along with an artificial intelligence (AI) system infused with its own rules and intentions, changes and transforms the virtual universe. Inspired by video games methodologies and technics, the embedded AI forms a universe which can exist and function independently from external influences and unlike traditional interactional spaces undergo through a number of evolutionary stages regardless if a performer chooses to interacts with it or not. This contributes to unpredictable results which constitute collaboration between the performer's input and the universe's pre-assigned intentions. The intelligent space works together with the performer by constantly listening and accepting gestural input and body movement data, both of which cause direct and indirect changes to the aesthetics of the space. These changes however, are not alone in creating the projected result but rather become an active part in the inherent evolutionary stages of the virtual ecosystem.

Marc Downie and Paul Kaiser, working in collaboration with choreographer Trisha Brown and her company, in their interactive performance work *how long does the subject linger on the edge of the volume…?* (2005)[1] created and projected little animated creatures (made from abstract shapes) which aim to travel from one side of the screen to the other by hitching rides on points in the motion captured dancer's bodies; in other words, the artificial creatures or avatars interact with the physically real performers according to their own programmed dispositions. The AI system tries to make sense of what it sees onstage in real time and the creatures, each with its own autonomy, try to follow the predefined intention they have been assigned (Birringer 2008, pp. 154-55). The motility of the agents is therefore guided by that intention, which in this case is to move from left to right. The camera vision system as the interfacing technology between the physical and the virtual realm observes the movement of the dancers on the stage and is acting as the creatures' visual perception. As the creatures move across the screen, the system needs to keep a constant track of their speed, orientation and location on the three dimensional space in order to identify the closest point to jump onto. Therefore, system variables as a digital form of proprioception keep track of all this information, and the system is informed, so to speak, by physical motion to which it responds. These three individual processes collect the necessary data for the interactions to work and subsequently feed it into the fourth main process which computes and produces the projected result. Even though this procedure might be common knowledge and practice for AI scientists and game programmers handling interactions, it has never been broken down, simplified, analyzed, adapted and theorized in an interactive live stage performance context, and it still remains largely uncharted territory for man dance and theatre practitioners who are not in a position to collaborate with computer and AI scientists. The second part of Chapter 3 builds up on Hansen's theory and proposes

[1] Trisha Brown Dance Company, with Paul Kaiser, Shelley Eshkar, Marc Downie (2005), *How long does the subject linger on the edge of the volume..?*. The full work, with the real time motion capturing system in place on stage, was first presented at Arizona State University, before traveling to New York City and, a year later, to the Monaco Dance Forum. On other tours, when Trisha Brown presented the dance, the real time system was not used and the projected graphics were "played back" to the choreography.

a theoretical framework of how such an intelligent 3d space can be designed, constructed and interfaced in order to be used in a dance performance.

Software for Artists: Structure and Organisation of the Thesis

Being driven by a high degree of motivation to learn and experiment with new technologies, artists often form workshops, research communities, online forums and platforms for exhibitions asking for creative feedback. However, since the technological tools available are generic, a number of problems might arise during implementation that might cause them having to change the conceptual idea to fit the technology. In an interview with Birringer, Marc Downie identified three problems with the current array of tools. Firstly, stating that there is only a very limited amount of them available, secondly that they are all the same and thirdly, nobody seems to care enough. He goes on to stress that interactive art "has had no effect on computers let alone culture at large. Digital artists continue to have no effect on Apple's next operating system, Adobe's next image editing tool, Microsoft's next word processor, Google's next start up purchase, W3C's next web standard, etc. This makes the idea that artists are content to simple wait for better tools all the more appalling" (Birringer 2008, pp. 276-77). Downie's solution is to create his own software to use, as well as make it freely available for anyone to use

After some experimentation with the common tools like Max-Msp/Jitter and Isadora, it was quite obvious to me that I could not use them for real time 3d visualizations. Jitter had some very basic integration for loading up 3d models but everything else seemed very limited. Populating a 3d space with models and playing back their animation is the starting point but what is really required in creating a space which is both gesture activated and intelligent, is exposure and access to resources which allow you to compile the required processes which will make the 3d world alive. By doing some further research I realized it was impossible to find a software tool which would perfectly fit my needs, just for the simple reasons that firstly, not many performance artists use real time 3d graphics and secondly, even if some did, their software was project specific and therefore not released to the public, exemplifying once more that Downie was right. Even though I had no sufficient expertise in programming languages at that point, it appeared that the only way to achieve the required results was to move a level down towards machine code, and migrate from readymade tools into scripting programming.

Inspired by the currently thriving computer games community, the great amount of free tutorials and resources and the dedication of individuals to constantly update and educate, I decided to experiment with Panda3d, an open source game engine created by Disney and then passed down to Carnegie Mellon

University to update, maintain and offer it back to the community. The “Code Theory” section in chapter 4 therefore begins with an introduction of Panda3d and the rest of the software I used to produce the complete platform. Following Downie’s example and the spirit of artistic collaborations, my full code is available for the community to download on my website for anyone wishing to use it or modify it.[2]

In the contemporary realm of digital art, a number of recent performances and installations are built by small multidisciplinary teams, including collaborations between artists and software engineers, as the artworks are heavily dependent on software. The on-going debate on how to improve communication between the two disciplines is an important matter which urgently needs addressing. Due to different character traits, artists and engineers have opposing work methodologies which can make communication between the two disciplines very difficult (Biswas 2008).[3] As creative and open-minded people (in many if not all cases) artists tend to work using a much more exploratory method as opposed to the majority of engineers who prefer a stricter, more structured approach. When a team starts working on an art project, usually the system software specifications are vague until the idea has passed through experimentation and a number of evolutionary stages, filtered through perception and experience.

On the other hand, engineers usually use a sequential design model (often referred to as the waterfall model) whereby they follow phases of conception, initiation, analysis, design, construction and testing. If the software specifications at the start of a project are not clear, then the code needs to constantly change making it in-efficient and non-re-usable. Artists on the other hand might underestimate new technologies, by not realizing the ‘under the hood’ complexity, the learning curve implementation, the instability and the lack of proper documentation and strong community. Furthermore, practical communication problems might arise, such as domain specific language terms and concepts, as well as underestimating the importance of the other domain. The priority of the engineer involved in an art project might be to showcase a new technology, whereas the artist may be focused on expressing a concept or an idea (Trifonova 2008).[4] Biswas proposes that artists don’t really need to acquire a deep understanding of technological principles but rather a broad one, to help them chose technologies for their projects, identify technological constrains, identify areas they might need help and make a correct recruiting (Biswas 2008, p. 86).

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[2] https://sites.google.com/site/dorosp/

[3] For an insightful discussion of the issues involved in arts and science research collaboration, see Joke Brouwer, Arjen Mulder, Anne Nigten, Laura Martz (eds), *aRt&D: Artistic Research and Development*, Rotterdam: V2_Publishing/NAi Publishers, 2005.

[4] See also Johannes Birringer’s critical analysis of iterative design processes in “User Testing for Participatory Artworks," *International Journal of Performance Arts and Digital Media* 1:2, pp. 147-73. This essay was revised and expanded into the chapter “Installations and the Participant-User,” in: *Performance, Technology, and Science*, New York: PAJ Publications 2008, pp. 179-213.

When a team is working in a complex, multi-dimensional and non-linear 3d scene the performer needs to identify and understand a number of actions, processes and possibilities. Even though I would in general agree with Biswas, I would argue that as far as 3d scenes are concerned knowing how the wheels are turned under the hood would greatly help the dancer to perform, the director to conceptualize, the interaction designer to show and discuss the possibilities and the rest of the team to relate, creating a scenario where the whole team co-creates the scene.

In the second part of the "Code Theory" section in chapter 4, I shall make an attempt to break down the processes I have identified in chapter 3 and explain the theory of the code required to produce them. I will not be using any strict computer software terms but rather pseudo-code in simple English, and I will be using the code from the *UKIYO (Moveable Worlds)* "creation scene" as an example. Due to the nature of the scene, the code for the 3d scene needs to be project specific. The processes which are applied though are easily re-usable by making a number of adjustments. Understanding the whole code might not be an easy task for an artist with minimal programming background, but the aim here is not necessarily to recreate the code but to comprehend the theory of how each process works, how the processes are combined together and the number of existing possibilities when the code is customized.

A full analysis of how the creation scene in *UKIYO (Moveable Worlds)* was conceived and implemented can be found in the first section of chapter 4, along with details of its contribution to the whole performance, the conceptual idea behind it, the planning and execution of the interaction system and a critical analysis. The chapter is divided into two parts, with the first part addressing the DAP Lab production *Suna no Onna*, a dance installation combining dance, interactive video and animation, fashion design and computer music. The work is explained from conception to execution, paying special attention to the animated backdrops and virtual avatars, which were my contribution to the dance installation.

The second part describes the mixed reality performance installation *UKIYO (Moveable Worlds)*, an immersive work of a dream-like fragmented world which stimulates perceptions and emotions by exploring kinesthetic relationships in a rich audiovisual narrative space spread across both the physical and the virtual realm. The performance was developed by the DAP Lab in collaboration with Butoh dancers and digital artists in Tokyo, Japan, as part of a cross-cultural research into virtual environments. Both performances have been directed by Johannes Birringer in collaboration with Michèle Danjoux. They feature work created by an international ensemble of artists from diverse creative backgrounds and feature experimental fashion concepts, wearable sensors, intelligent fabrics, real time music generation as well as interactive video, images and animations.

My objectives with this thesis are threefold. Firstly, I am investigating the technological methodology as well as the instruments and the code required to create a gesture activated and body movement controlled real time virtual 3d world. A special attention is paid to ensure that the production processes are transparent and easy to understand by not only computer engineers but more importantly by team members with less technological expertise, as well as artists aspiring to engage interactive 3d media. Secondly, deriving from existing phenomenological theories I propose a theoretical framework on which I am basing my conceptual methodology. Finally, by looking at my two practice-based artistic productions and case studies which have been completed during the four years of my study, I shall put into practice both the technological and the theoretical ideas delineated in the first and second part of this thesis. An overview and analysis of the findings will be addressed in the final concluding chapter.

I start with an introduction on the background of digital performances and interactivity, briefly mentioning the evolutionary stages that led to their contemporary development. I shall then investigate the technological possibilities, using current knowledge and announced upcoming technology, of both a disembodied reality as well as augmented mixed reality in a performance context. Next follows an investigation of the critical issue of projected representation of the 3d space, by looking at its historical evolution and referencing related domains such as films, animations and digital games. The theoretical section begins by investigating Mark Hansen's expansions on Merleau-Ponty's phenomenological ideas shifting the attention from occularcentrism to movement and physical activity, an idea that explicitly emphasizes the physicality of dance.

Building further on Hansen's views and identifying the need to compose a framework for my proposed methodology, I suggest the idea of the space-schema, a system encompassing a number of required processes which a designer can use as a base to build an interactive real time 3d space for performance use and the potential interpretive or improvisational creativity of a dancer or actor. Finally, by referring to the case studies, I aim firstly with *Suna no Onna* to introduce the idea of sensor interactivity, wearable design and real time controlled animations in a performance context and to explain how this performance acted as an evolutionary step to interactive digital performances. Furthermore, with *UKIYO (Moveable Worlds),* my aim is to show how my theory and methodology is put in practice along with new technologies to create an interactive real time 3d work. As the scope of this thesis extends beyond just conceptualizing how the processes work, but also demonstrating how the interactions function both independently and how they come together, in the next section I shall break down and analyze the code. Evaluations of the methods and technics, as well as the findings are offered in the last chapter.

Immersion – Theory and Technology

The Bifurcated Body

I will start this section by giving a definition to the terms immersion and embodiment thus giving a context for my arguments. I will then continue to analyze the importance of the physical body in a virtual reality (VR) simulation, arguing that since we are trained to interact and perceive the world in a way that accommodates our everyday life interactions and experiences, adjusting our perception to work in a virtual environment (VE) is a process that requires time, effort and dedication. I will briefly touch on the subject of disembodiment and the Cartesian split and differentiate it from the notion of mixed and augmented reality, covering the two main domains of virtual reality. I will then proceed to analyze current and upcoming virtual reality techniques, technologies and instruments that work towards technological embodiment and comment on their potential use in art projects and installations. In the final section of this chapter, I will firstly address these core concepts from a performative perspective by investigating three different but equally important examples and secondly propose methodologies for improving the immersion qualities of gesture and body controlled 3d interactive spaces.

As it is widely accepted there are no agreed universal definitions on immersion and embodiment, it is important before moving on to put them in context. When I refer to embodiment throughout this thesis, I will be referring to a state where one has the ability to interact as well as receive and cause stimuli and experiences within a given space. Immersion on the other hand, is the process by which embodiment is achieved. Everything that causes a perception to shift from one realm to another will be considered as an immersion technique. This does not only include the visualization hardware, but also aspects such as social environments, realistic or stimulating interactions, narrative and everything else that constitutes a deeper level of connection to another realm. As we are also considering the idea of disembodiment and the Cartesian split, it is necessary to assume the existence of a consciousness and a bifurcated body.

A human can be considered to be completely embodied in the perception of an everyday life reality, but that does not act as a limiting factor. The same person can be also partially embodied to an alternate realm as long as there is interaction and exchange of stimuli and experiences taking place in the second realm as well. An example of this can be a virtual realm mediated with technology. Getting completely immersed to the virtual realm would constitute temporarily abandoning the physical body and having one’s consciousness enter the virtual space. That would assume that the physical body is in an idle state, ceasing any connection with the physical realm. Science fiction writers and film directors have been envisioning this idea for some time now. In the film *The Matrix* (Larry and Andy Wachowski, 1999) Neo finds himself waking up in a liquid-filled pod with his body connected onto a network of machines through a socket in his skull. We learn that what he thought was the real world was in fact a simulated reality referred to as “the matrix” and in fact his real body was idle and used as a power source, along with the rest of the embodied humans, to fuel the machines.

The idea of disembodiment was suggested by the philosopher René Descartes in the 17th century. In his unfinished treatise *The Description of the Human Body* Descartes describes the human body as a machine, where heat from the heart causes all the movement in the body. Veins, just like pipes, carry blood from all parts of the body towards the heart, where it servers as nourishment for the heat which is there. He believed that the most agitated and lively part of the blood would be taken to the brain where it would compose a subtle wind, called the animal spirit or the soul, that enabled the brain to experience, think and imagine (Ross 1975). The soul, according to Descartes, is in fact a separate nonmaterial entity that exists inside and controls the body. This idea had been proposed also by Plato centuries before who believed that the body is from the material world whereas the soul is from the world of ideas, united temporarily with the body and separated at death when it would return to the world of Forms. This dichotomy of the body and soul – commonly referred to as dualism or the Cartesian split – serves as the basis of modern ideas about disembodiment, inhabitation of virtual avatars and transfer of consciousness from one body to another.

The idea of dualism has been disputed by a number of theorists and philosophers such as Parmenides and Spinoza; nonetheless it remains a favorite for fictional writing and conceptual ideas. As technology is becoming advanced enough to start experimenting with virtual reality concepts, the realization that transcending the physical body by means of a brain-computer interface is not a realistic possibility at the moment has urged researchers to investigate alternative immersion techniques. Most of the research undertaken at present center around the visual aspect of the experience, from head mounted displays worn on the user, to CAVE rooms with the projected image covering the whole room. One of the main difference between VR and cinema is that in a VR environment the projected image displayed is no longer chosen by a director but instead is a product of the resulting actions of the user. This essentially makes viewing, interacting and navigating a 3d space a user experience.

A number of different definitions have been proposed for immersion and embodiment, depending on how the subject is approached. Witmer and Singer propose that embodiment (or presence as they refer to it) is induced by a combination of immersion with involvement. They define it as “a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences” (Witmer & Singer 1998, p. 227). They continue to say that immersion in a VE (a) requires the function of isolation from the stimuli of the real world, (b) assumes the perception of self-inclusion in the VE, (c) it has a natural mode of interaction with the VE and (d) there is a perception of self-motion through the VE. On the other hand, Slater and Wilbur define immersion as a list of technologies which are required to induce presence. They argue that in order to be immersed, one needs to be surrounded, and the only way to achieve this is by using display technologies such as head mounted displays which block out real world stimuli and provide stimuli coming from the VE. They further suggest that one can measure the degree of immersion by simply stating the display technology used (Slater and Wilbur 1999).

Jacquelyn Ford Morie, looking at immersion from a phenomenological point of view, argues in her paper "Performing in (virtual) spaces: Embodiment and being in virtual environments" that "VEs engage the body as kinesthetic input via the specialized interface devices that not only permit but *require* bodily actions to be performed sensorially, kinesthetically and proprioceptively – within a full 3d spatial yet virtual construct" (Morie 2007, p.126). She goes on to mention that since our perception is mediated by the VR equipment, we must try and understand what constitutes a mediated environment. By referring to VR expert and psychologist Jack Loomis, she equates a mediated environment as the "unaware state most people have of their embodied existence". Essentially Loomis states that the contact with the physical world is mediated by the perceptual world created by our senses and nervous system. Morie furthermore argues that our body, existing in our current reality, becomes the vehicle that compels the neurons to form patterns of connectivity. Those patterns turn into experiences, which form the mind which makes sense of them. Thus how we perceive the world depend on these experiences which originate from the body. When VR technology is introduced into the equation, these dynamics are changed, since now we have no body, or at least no body as we know it from our current reality, to form experiences. Our perception is now mediated by technology.

Many VR pioneers suggest that participants enter the world of the virtual and leave their bodies "behind". Morie argues that "The body of the participant is synchronous subsumed into the virtual self that enters the world within the screen, which is created in the mind from what the body experiences" (ibid). She believes that while someone is inside the virtual, there is still awareness of the physical world, and that is exactly what makes the concept of embodiment so elusive. At some level we are aware of our duel perceptions and in order to shift them entirely to one side, one needs a really deep connection with the virtual, such as the one described by Csikszentmihaly (1997), in his famous model of a state of flow. Loomis states that "The perceptual world created by our senses and the nervous system is functional as a representation of the physical world that most people live out their lives without ever suspecting that contact with the physical world is mediated…" (Loomis, 1992, p. 115). It is therefore that the perception of our world depends on our interaction and experiences of it. It is interesting to see how Morie takes this a step forward, arguing that the relationship between the body and the experiences is entwined. She says that the “body shapes who we become by compelling our neurons to form their intricate and scintillating patterns of connectivity. Experience affects how we think, feel and understand our place in the external world, and it does this by forming the mind which we make sense of it” (Morie, 2007, p. 126).

Theorists and practitioners working with gaming concepts seem to agree with Morie’s views on generating experiences. Brown and Cairns in their paper “A grounded investigation of game immersion” argue that in order for a high level of immersion to be reached (referred to as total immersion) the user first needs to pass first from two other stages, namely engagement and engrossment (Brown,Cairns 2004). They have come to this conclusion by carrying out a simple experiment. They let gamers play their favorite game for a time of up to 30 minutes and then they asked them a number of questions. They discovered that in order for the user to be engaged there must be fluidity in the interaction controls and willingness for attention. Furthermore the user must devote a decent amount of time and effort at the task. They concluded that engagement is easily reachable and most people playing digital games can achieve it. The next step is engrossment. Here according to the authors is what distinguishes a good game from an average one, and reaching this stage can result in a deeper level of immersion. Brown and Cairns propose that “Gamers could tell when a game was well constructed and could see when designers put effort into construction … At this level of immersion due to the time, effort and attention put in there is a high level of emotional investment in the game. This investment makes people want to keep playing and can lead to people feeling emotionally drained when they stop playing. The game becomes the most important part of the gamers’ attention and their emotions are directly affected by it” (Brown,Cairns 2004). They claim during after engrossment, the gamer is less aware of their surroundings and less self-aware than before.

The next step after this is total immersion. In order for this stage to be reached, the player not only needs to be engrossed by also feel empathy towards the main character. Furthermore the atmosphere of the game, an extension of how well the game is constructed, needs to be relevant to the action and location of the game characters thus requiring full multi-sensorial attention from the user. “The level of immersion felt by gamers seems to correlate to the number of attentional sources needed as well as the amount of each attentional type. The games seem to play with three elements of attention: visual, auditory and mental” (ibid, p.1299).

Berthouze and al, in their studies of game player behavior, explored engagement on the basis of body movement of the player. The question they specifically address is whether an increase in task-related body movement imposed or allowed by the game controller will result in an increase of the player’s engagement level. They conducted two experiments by playing the same game but by alternating the controller. In the first one the players used an ordinary PlayStation controller, and in the second one game's own guitar controller. According to their findings the body movement appeared to "not only increase the players' level of engagement but also to modify the way they get engaged". The players appeared to quickly enter the role suggested by the game, here a musician, and started to perform task related motions that were not required by the game itself (Bianchi-Berthouze 2007, p.111).

In the first part of her paper, Morie makes a thorough investigation of how theorists and practitioners of digital art have revisited the significance of the body in the digital age. Even though she identifies artists such as Stelarc and Movarec who both expressed extreme views on the absolution of the body, she claims that "recent findings from neuroscience are supporting and justifying a mind/body union, finding extreme interdependencies between our brain's development and our embodied human state" (Morie 2007, p.129). She credits the work of Antonio Damasio and other neuroscientists (Edelman, LeDoux and Schaster) that showed that the body and how it experiences the world is responsible for the complicated interweaving of neuronal connections in our brain, out of which our mind – and perhaps consciousness itself – is constructed" (ibid, p.125). Furthermore, she quotes from Lakoff and Johnson's foundation work, *The Philosophy of Mind*, a work which strongly debunks the thought that human minds are like computer software but rather they acquire meaning through their living bodies.

Philosophers of phenomenology, and especially Merleau-Ponty (more of whose ideas and thoughts will be examined in chapter 3), give great significance to the body as a means of perceiving the world and the human experience. Merleau-Ponty describes the body and space as an "Experience that discloses beneath objective space, in which the body eventually finds its place, a primitive spatiality of which experience is merely the outer covering and which merges with the body's very being. To be a body, is to be tied to a certain world. Our body is primarily in space: it is of it" (Merleau-Ponty 2002). Morie, concluding on the subject, mentions that the reason embodiment has been so elusive to us so far, is because inside the virtual we are still aware that we are in the physical world. The lived body is bifurcated and became two, but at some level we are still aware of our dual perceptions.

Future Technologies

In the persuit of a system with optimal immersion qualities, in this section I will investigate and analyse current and upcoming technologies. I will explore both the possibilities that can lead to the eventual creation of a computer-brain interface suitable of creating a disembodied experience as well as technologies focused on immersive audio-visual and haptic environments. The purpose of this section is primarily to inspire the curiosity of the reader by considering the use of upcoming technologies in art work contexts, and how the might shape future works when using 'top of the range' technologies and techniques. As universities and research institutions have usually a limited amount of budget, knowing the technological possibilities is essential in order to make the best choices in what to pursue. Making a good choice on what hardware to seek access to is essential since the market is getting saturated with possibilities. Furthermore, choosing good collaborators can be vital for the success of a project. There are two considerations which need to be taken into account here. Firstly, as we are entering well into the digital age, the prices of electronics have dropped considerably and that aided with the expansion and easier distribution of knowledge and multi-disciplinary research, acquiring or even creating new technologies to be used in art projects is not restricted to big budget institutions any more. Secondly, as technology is moving ahead at a very fast pace, this list is not meant to act as a reference but rather as a way of demonstrating the method, filtering and analysis of future technology aimed towards a community of artists. This research was done prior of commencing the *Ukiyo (Moevable Worlds)* practical work, but it has been updated while finalizing the thesis to provide information about the latest technologies.

American author, inventor and futurist Ray Kurzweil, famous for his views on the technological future, predicted in his latest book *The Singularity is Near* (2005) that the next phase in VR technology will be to project images right onto the retina, and that doing so will create a full audio visual immersive environment which will be merged with the physical space. One would be able to walk around and feel like he or she is in a different space, becoming part of an embodied or mixed reality. He continues further by saying that in 20 to 25 years, nanotechnology would be advanced enough to allow humans to inject nanobots in their body which would be able to control the nervous system directly. So in theory the nanobots can shut down the signals coming from the real skin creating signals that will be appropriate for the virtual environment. One would be able to see, feel, touch, talk and interact through a virtual avatar the same way she would with her physical body. Technology though will mediate, transferring one's will on the avatar. This can create experiences in a VE that can be both within and beyond the abilities of the human body.

Accepting the notion proposed by Kurzweil it is interesting to investigate who technologies currently explore the notion of a brain-computer interface. Emotiv (Emotiv, 2010), a company doing research on Electroencephalography (EEG), recently demonstrated in a presentation their new lightweight personal brain computer interaction system. Their technology comes with software that enables the user to easily connect with a virtual environment and manipulate 3d objects. In their demonstration, they showed how one can push, pull and make a cube disappear. The technology first requires a calibration, which they called mapping. The user imagines for 8 seconds the cube being pulled towards him/her, and the software records the brain waves emitted during this time. As soon as the calibration is over, whenever the user thinks about pulling, the software recognizes the brain waves and pulls the cube. Push and pull are concepts which one can visualize clearly in one’s mind; therefore a direct connection is easy enough to be established. Imagining something to disappear though is not a concept that one thinks often. During the calibration period the user thinks about the cube disappearing from sight, and the brain waves are again mapped, and this can be repeated at will. This requires more practice as the thought of something disappearing is a new concept to the user but during their demonstration this worked out really well even to a novice user. Therefore using the concept of mapping the ability to perform out of the ordinary tasks becomes a possibility. Applying this concept to Kurzweil's predictions it becomes easy to imagine this concept used in making virtual avatars perform feats which are impossible with the human body, such as flying or teleporting. Even though EEG readers have been around for quite some time, it is not until recently that they become affordable enough for a variety of research institutions to experiment with.

Star Trek has popularized the idea of the Holodeck, and by many VR pioneers it is considered to be the ultimate mixed reality experience. A simple explanation for how the Holodeck functions in the Sci-Fi series can be found in Wikipedia: "The holodeck is depicted as an enclosed room in which objects and people are simulated by a combination of replicated matter, tractor beams, and shaped force fields onto which holographic images are projected. Sounds and smells are simulated by speakers and fragranced fluid atomizers, respectively. The feel of a large environment is simulated by suspending the participants on force fields which move with their feet, keeping them from reaching the walls of the room (a virtual treadmill)". Developing an interactive holographic room consists of a number of different technologies, which I will break down to: Visual projections, haptic technologies, navigation and tracking.

Even though interactive holographic projections would certainly create an immersive and engaging environment, unfortunately we are still not quite there yet. Right now cave environments and cinema theatres are working with 3 different 3d Stereo display methods. Anaglyph glasses, Polarized glasses and Shutter glasses, with the last one being the preferred method for the new 3d home televisions. These technologies have existed for a long time but only recently, with the introduction of 3d cameras and the release of *Avatar* people have started to understand the true potentials. In 2011, a number of companies have been experimenting with glassless 3d technologies – the Nintendo 3ds and the LG Thrill 4G are two examples of glassless 3d mobile technology both released in the last two years – but TVs and movie theaters are set to follow shortly, with Apple, Eizo and Sony all reported to work on new versions of their technologies.

At the Nvidia GPU Conference this year (21^{st} – 24^{th} of September, 2010) there was a really interesting showcase by a company called Micoy (Micoy, 2007).They claim that their technology can project 3d images in a full 360-degree environment. Current technologies, as used for example in the film *Avatar,* are based on projecting an image onto a flat screen. Therefore there is a single focusing point and as a result the 3d draws your eyes into the screen. Micoy's 3d rendering technology is based on a curved screen with infinite focal points, which makes one feel that the images "fill" the space between you and the screen. It still does require glasses (Shutter glasses working at 120 HZ), and it does assume that the set up will be hemispherical.

Researchers at the University of Tokyo, experimenting with touchable holography, have developed a system (Takayuki Iwamoto 2008) made up from a simple holographic display screen, a tracking system and an "Airborne Ultrasound Tactile" display unit. This unit shoots focused ultrasonic waves at the hand to create the sensation of pressure on the skin. Currently it can only create a 1.6grams force of pressure within 20 millimeter wide focal length, barely capable of producing the effect of rain drops but is an important step towards tactile immersion. Their work has been presented at SIGGRAPH 2009.

In the 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems, De Luca from the Sapienza University in Rome have introduced CyberWalk, an omni-directional navigation platform that adjusts its speed and direction to allow for unlimited exploration of a virtual space (De Luca 2009). It consists of an array of synchronous linear belts which move as a whole in one direction while each belt can also move in a perpendicular direction. Diagonal movement is also possible by combining the two linear motions. By monitoring the position of the user on the platform (using a Vicon motion capture system) the controller calculates the two variables and tries to adjust the speed of the linear belts to keep the user to the center.

Finally, one last piece of hardware that needs mentioning is Microsoft's recently released "Kinect" sensor. It is made as a peripheral for their gaming platform x-box 360 and allows users to interact through a natural user interface using gestures and spoken commands discarding the need of a game controller. The device features an RGB camera, a depth sensor and a multi-array microphone running software which provides full-body 3d motion capture and facial/voice recognition. The sensor was released in November 2010, and since then hackers managed to hook it up to the PC and extract the 3d data. Since it works with ambience lighting and requires no special one color background, it is currently by far the most efficient way to achieve real time motion tracking. The sensor was unfortunately released a few months too late for using it for the *Ukiyo(Moveable Worlds)* project but it has already shown its potentials and is becoming very quickly a favorite for the hacker community[5].

All the above mentioned technologies are working towards a complete immersive system. Identifying in which direction the technology is headed can help university research centers and artists working on long term projects plans formulate ideas which by the time they are fully implemented and presented will be

[5] This is a video of my latest experiments using the Kinect Sensor http://www.youtube.com/watch?v=dNzPpkteUZ8

utilizing brand new technologies which have just been released, increasing perhaps the influence that digital art is exerting on computers and the culture at large.

Immersion in Dance Performances

Even though a number of artists, including Julie Bokowiecz and Todd Winkler, have experimented with immersive kinaesonic environments and interactive sensorial multimedia productions, identifying a performance where the performer is immersed in a 3d world has been proven difficult. In this section I shall analyze three well known performances by Char Davies, Troika Ranch and Trisha Brown's company collaborating with Marc Downie and Paul Kaiser. All three productions can be considered immersive in different ways, and my aim here is to identify and propose an opinion towards the effectiveness on the immersion qualities of each.

The first work that I would like to address is *Osmose*, a VR installation by Char Davies and her development team at the 3d software SoftImage. The installation was designed to explore the potential of immersive virtual spaces to allow participants to shed their habitual ways of looking at (and behaving in) the world. One of the primary goals of Char Davies was to "push the expressive capabilities of existing 3d tools, to demonstrate that an alternative aesthetic and interactive sensibility is possible for real-time, interactive, 3d computer graphics" (Davies, Harrison 1996). The navigation in *Osmose* is modeled on scuba diving, an activity that Davies has extensive experience in. The "immersant" as she chose to call the user of the installation controls navigation by the intuitive process of balance and breathing. Leaning forward moves the body forward, leaning back moves the body backward, and by breathing in the body is elevated whereas by breathing out the body descents. The visuals were highly praised as Davies collaborated with SoftImage, a company at the forefront of computer graphics at the time. The highly innovative use of this navigation technique worked towards increasing the immersion level of the user by stimulating an alternative state of consciousness within the virtual space (a more thorough analysis on navigation will be given in the next chapter).

Even though only one person could be "immersed" at any given time, an audience could watch his or her journey through the virtual world on a large projection screen. As Davies explains "The view of *Osmose* that the participant saw was also projected in real time in 3D on a large screen in the audience area – so that with polarized glasses, the audience could vicariously experience the space…The shadow of the immersant was projected on a vertical translucent screen which was also visible in the audience space, facing the video screen. This helped emphasize the role of the body, poeticizing the movements of the immersant, and highlighting the relationship between body gestures and the resulting visuals and sounds" (ibid, 26).

There is no doubt that *Osmose* was an innovative, impressive installation. As a work of art it has introduced to the users an immersive audio visual experience that some of them even considered a life changing experience. As I am investigating immersion as viewed from the point of view of the audience, one has to wonder though how interesting it was to the people watching it from the outside. Does watching someone else navigate through virtual space offer anything else than a moment of awe (mainly to the interesting advance graphics of that time) and maybe for the more adventurous ones a lust to try out the technology by themselves? Manovich described it in this way: "The immersant thus becomes a kind of ship captain, taking the audience along on a journey; like a captain, she occupies a visible and symbolically marked position, being responsible for the audience's aesthetic experience" (Manovich 2001, p. 261). The main focus of the installation of course was the individual experience but the question on whether the agency of the immersant can be transferred to an audience is certainly an interesting one.

Troika Ranch's *16 (R)evolutions* (2005)[6] is a dance performance with real time projected graphics, generated by a system which analyses the movements of the dancers. As Birringer described it "the interactivity is no longer focused on direct mapping of gesture but on the creation of complex 'action paintings,' calligraphies of human gesture translated into image flows … (The software) recognizes the change of direction, speed, dynamics and velocity of movement within these categories, the program then renders the graphic output in real time, and we can perceive the three-dimensional dance and the projected 3D worlds of colors and shapes" (Birringer 2007, p.24). Even though this cannot be defined as an immersive environment (from the point of view of the performer) in the same sense as *Osmose* can, it may still be perceived as immersive from the audience point of view. The dancers here are performing, along with a system that is waiting for an input to analyze, compute and project a visual output onto the screens. The audience experiences a totality, the complete work of body, music, visuals merging together as one, whereas the performers feel all around them the energy of their bodies being extended amplifying their presence on stage in their own hyper reality. Further examples of this category include work by Chunky Move, such as *Glow* and *Mortal Engine*, the performance *Is you me* by Louise Lecavalier and Benoît Lachambre (with Laurent Goldring and Hahn Rowe), and *(Re)Traces* by Tanja Raman + Dbini Industries, all of which deploying interactive real time systems that augment performed motion with graphic behaviors responding to and extenuating the movement expressions.

The next and final work I want to briefly mention is Trisha's Brown stage work, *how long does the subject linger on the edge of the volume…*(2006). This work "interfaces animated graphics from real time motion capture driven by an artistic designed artificial-intelligence software which responds to kinematic data and generates particular behaviors" (Birringer 2007, p. 27). Projected tiny graphic agents on a

[6] Coniglio, Mark. & Stoppiello, Dawn (2006, 18/1) 16 (R)evolutions. Eyebeam Arts & Technology Center, New York.

transparent screen try to make sense of the dancers' trails, with the intention of hitching a ride from the right side of the stage to the left. These graphic agents have an artificial intelligence and, in an almost game like environment, they have a purpose. It is very exciting and interesting to watch, considering that even though they are acting independandly, the agents and the dancers are still very strongly connected. While the agents are trapped in a 2 dimensional plane waiting idly for a trail, the algorithmic code behind them keeps looping, searching for a way forward. The code gave them an one track mind, capable of only recognizing motion trails and nothing else in their environment, not even each other. The dancers on the other hand, perform a choreography together completely ignoring the graphical agents. The choreography is fixed, but since the system is analyzing the dance moves in real time, a simple change in position or speed can distinguish the movement of the agents from one show to the next. Looking for the immersion techniques in this performance it is obvious that there is none from the dancers' perspective in respect to the virtual. Investigating from the audience perspective, it is also clear that even though there is a connection, the dancers and the agents exist in completely different but somehow inter-connected realities. So there is not a sense of immersion there either. The only elements in the whole performance that can be considered immersed are the graphical agents, which are interacting with a digitized form of the performers' movement trails. They live in their own reality and even though they have limited intelligence they still have a perception of the environment, a spatial sense of speed and direction and a purpose. They exist in their own reality, interactive with past, present and future (Birringer 2008, p. 264). The audience, being in an even further away dimension from both dancers and agents witnesses the whole experience, without having the power to interact with neither.

By thinking about the three different pieces, we can see three different kinds of immersion. As we are concentrating on performances for an audience, it is important to consider which kind offers the audience a better experience. In second generation Interactive systems, such as *(R)evolutions,* the audience are probably experiencing the best results, since they create the illusion of immersion for them. *Osmosis,* on the other hand, even though the user gets more immersed into the action, offers less of an interesting experience to the audience since they cannot really feel the responsive behavior. It is remarkable to see how interactivity has evolved and how this affects immersion. In the first generation of interactive systems, we have a direct one-to-one mapping, where an action causes an immediate reaction. These systems have been used for 30 years now and they are considered to be boring, repetitive and offer no more food for thought. In the second generation, an action causes a non direct correlated reaction; when the choreography is not primarily concerned with triggering responses, it creates a flow which can be considered pleasant to watch by an audience. The correlations between the action and reaction are quite obvious to intuit, easing the mind from looking for a relationship. At the same time, however, they can be variable and unpredictable enough so they do not become boring. This can be seen working very effectively in Chunky Move's performances. The introduction of AI, as seen in *how long…,* is adding a second dimension to the performance by introducing autonomous elements to the performance. Does this enhance immersion though? I would argue towards 'no' in this case since there is no direct correlation between the physical dancers and the agents.

Immersion: Space

One way of investigating further how immersion can be improved is by trying to adjust methodologies from alternative mediums. Computer games are known for producing high states of immersion, mostly due to the ability of the player to create changes in the world (commonly referred to as agency). Before moving on though, it is important to state the differences in creating the two spaces. When a game designer is designing a space for a game, completely different approaches are taken from designing a space for a dance. A gamer (or an online VE explorer, for that matter) by accepting to be immersed in a VE is making a much bigger commitment to the space than a dancer. The gamer is becoming immersed with the assumption that he will spent time and effort in understanding and exploring the space and in return expects to be rewarded, whether that reward comes in the form of social interaction, mental satisfaction or just an enjoyable passage of time. Therefore the space needs to be much more complicated and intriguing, making the gamer feel that no matter how much exploration he or she made, there is still opportunity for more.

A way to achieve this is by having a constantly changing and evolving world which is part of a narrative. The gamer wants to feel important, desiring the satisfaction that she can accomplish change and placing that under a narrative structure gives her context. On the other hand, immersive environments in art installations/performances have time constrains. They need to be short and interesting. In installations the user will only be immersed for a short amount of time and probably the experience will not be repeated a second time. Therefore, the size of the VE needs to strike a balance between making the user feel satisfied with the amount of exploration achieved and at the same time showing the non-linearity of the space by making the user understand that there are alternative pathways to explore. There is no need for a narrative because there won't be enough time to make it complicated enough to be enjoyable (unless of course the user makes a narrative out of the space by herself) and there is also no need for scenarios investing a long term changing space because there will be no time for that to be noticeable. In a dance context, it becomes even more complicated. The performer needs to be immersed in a VE and at the same time direct her actions to the attention of an audience. Can the performer's agency be interesting for an audience?

Creating a complicated, constantly changing and evolving VE which can be suitable for a dance performance requires much further experimentation. The main issue is finding a way to relate the environment to the performer. The interactions need to happen fluidly and in an obvious way to the audience so their mind can be at ease, not wasting time looking for relationships. There must be a flow to the whole performance, preferably with a start and a conclusion but at the same time the world must be evolving, creating performances operating at a non-liner fashion which convinces the audiences that the interactions have a meaning and a purpose. Virtual agents will need to interact with the environment both autonomously and along with the performer demonstrating once more the complete ecosystem the performer is part of. It is important to show that this is a living, breathing world that has no need for the performer's actions in order to exist. This way we have a performer entering a pre-existing autonomous space, creating the illusion of continuity. A simple example of the effectiveness of this is to think of an online virtual world like *Second life* or *World of Warcraft*. When one joins one of these spaces there is an immediate sense of belonging and the user feels part of a populated world bursting with life. By taking the AI a step further and creating rich complex environments with dynamic rules, physics, encapsulated time and interconnected entities we can create an environment with much deeper immersion possibilities.

As an audience is faced with a projected VE a question of its purpose might pop into their mind. In *how long...* the purpose of the virtual space was revealed to the audience slowly, allowing them to watch, question, think and connect the dots by themselves. In more complex environments this becomes more complicated due to the large quantity of information and the three dimensional movement through the space. Abstract movements around the space, even though they can be appreciated for their poetic value by an immersed user triggering them, will not have the same effect with an observing audience. Therefore a more immediate purpose for the existence of the VE needs to be provided. Based on these thoughts, I would argue that a narrative might be one way to solve these problems. The performer has a reason to be in the space, has a task to accomplish, a story to take forward. The audience watches the immersed user going on a journey with a purpose, taking them along for the ride.

Immersion: Performer

Having a space that appears to contain immersive potentialities, like for example a vivid, populated world, is still not enough unless the performer has a way to impose a material and a kinesthetic presence inside the space. The majority of the current installations and dance performances try to follow a methodology of gestural analysis and movement recognition of a stage performer by using systems that observe and analyze movements as they are performed in the physical space. Erin Manning, in her introduction to *Relatioscapes: Movement, Art, Philosophy* argues against establishing a library of mapped gestures as this would “tie the body to some pre-established understanding of how it actualizes” (Manning 2009, p.61). Instead, she proposes to explore the potential of the wholeness of movement including its “unmappable” virtuality. The ”unmappable”, an aspect of movement she calls pre-acceleration, is a tendency towards movement through which a displacement takes form (Manning 2009, pp.61 – 62). Manning, wanting to avoid conditioning the body to facilitate pre-established actions and movements, proposes to seek alternative methods to give and translate the meaning of dance language and its representation in the virtual space.

Due to the nature of gestural analysis, in order to be identified gestures need to be broken down into a number of cycles with a start and an end time therefore secluding them from the intention and the actions which preceded them. In consequence the fragmented digitized movement loses the flow of the dance produced by the performer and instead it is rebuilt as a re-stitched, technology mediated sequence. Gestural/movement analysis is implemented as a method to transfer the energy of the material presence and movement from the physical to the virtual realm. I would argue that as far as interactional 3d worlds are concerned, a new methodology needs to be developed which bypasses the process of gestural recognition and instead transfer the whole, uninterrupted movement in the 3d virtual domain, allowing a real time manipulation of the space fabric. The changes and interactions of the virtual space need to originate from inside the very same medium and not as mediated signals from another realm.

I would propose that instead of concentrating the majority of the resources in investigating gestural analysis, more attention needs to be diverted in exploring ways to replicate and use, in real time, the uninterrupted movement of the performer. This would still involve technological mediation but the data would still retain its raw, un-fragmented form. A digital copy or a mirrored outline of the performer can form an existence in the digital realm performing the choreography as intended and interacting with the space from the inside. Falling particles can collide with the material body, footsteps can leave a mark on the virtual space, and the performer can push, pull and shape malleable architecture.

Even though motion capture technology has been around for a number of years, experimentations in the dance world with real time interactive worlds have been sparse, mostly due to the limited availability of the hardware, the long set up and the awkward, cumbersome interface. Furthermore, past investigations were mostly performed to experiment with the visual aesthetics of puppetry in non-responsive environments, completely ignoring the offered potentials in movement analysis, spatial awareness, navigation qualities and immersive properties. With the recent availability of hardware sensors like the “Kinect” the process can be greatly simplified, eliminating the need for any physical components to weight down the performer. Creating the digital doppelganger consists of mapping a virtual skeleton onto the performer as she/he moves in the physical space. The skeleton subsequently maps and mirrors the movement on a 3d model (which the identical virtual skeleton attached) in the virtual realm.

Using this method ensures that not only the movement is transferred flawlessly but also the existence of a material presence on which the movement is applied on. The material presence initiates a number of new possibilities which did not exist with traditional gesture analysis. Firstly, movement in the 3d virtual space acquires a renewed context in which a body cooperates with mass and volume subjected to the physical properties of the space, resulting in more elaborate simulation of the body / space relationship. By replicating the kinosphere of the performer in the virtual space, affective interactions can take renewed meaning rekindling the promises of first generation interactivity. Body parts can now have corresponding virtual limbs allowing them to touch, push, pull and trigger virtual objects the same way they would in the physical space. A virtual camera can be also attached on the head of the performer rendering the corresponding first person view of the environment. Furthermore by analyzing the data captured in the kinosphere, the movement can now be analyzed in 3 dimensional patterns. This ensures that no data is lost during digitization and analysis of more complex patterns leading to processes which can fuel more efficiently the second generation of interactive systems.

As a final note, I would like to propose that this system of 3d gestural and movement analysis does not need to be limited to performances or installations that contain 3d content and/or worlds, but rather it can be used by any work which requires a more methodical analysis. The system can run in the background performing an analysis of the performer in captured 3d space and feeding the data to the main processing patch which would render the projected result.

Navigation and the Camera

Before one starts talking about a 3d VE, it is important to provide a differentiation from other spatial mediums. Paintings, maps, comics and traditional cartoons are all examples that utilize a 2d spatial medium. Their creators draw on single plane layers of superimposed images as seen from a single view point. 3d worlds work differently. The addition of the 3rd dimension, depth, eliminates the flat plane and instead creates a volumetric vacuum. The creator therefore can place 3d objects as well as virtual cameras into the space creating an environment that can be viewed from an infinite number of viewpoints. One might ask though if a 3d space is represented on a 2d surface, like a wall or a screen, how does that differ in the observers' perspective from a 2d image? If a 3d environment is looked at as individual still frames then there is no noticeable difference. However, 3d virtual spaces, just like films, are not meant to be seen as static images. Not only do the 3d objects have the ability to move around in space but a flow of movement can happen through them in all 3 dimensions, changing continuously the camera's viewpoint. This movement is called navigation, and it can be the cause of either a user's interaction or of the system acting on its own.

Before moving on I would like to define four terms which will be used in the following section. *Navigation control* is the physical controller that the user of the VE is using (e.g. Joystick, sensors). *Navigation method* is the way movement is portrayed in the VE (e.g. the user is driving a car, the user is controlling a walking avatar) and *camera view* is viewpoint of the virtual camera from which the user is viewing the VE. The term *navigation structure* will function as an encapsulation of all three terms.

Since I am here referring to 3d environments that were mostly created for interaction by a user, the navigation method and the camera view have a more functional than an aesthetic use as opposed to animated movies, for example. Therefore it is common practice to create them as application specific depending on the task at hand and the intended navigation controls. There is not one commonly accepted navigational structure, and it is fair to say that there are no current theoretical frameworks for someone to investigate.

Historical Examples of Navigational Spaces

I will continue by looking at a few examples from classic navigational spaces, as delineated by Lev Manovich. The first interactive virtual navigational space is acknowledged to be the 1978 *Aspen Movie Map* project developed by the MIT Media Laboratory (it was called MIT Architecture Machine Group at that point). This project did not feature any 3d graphics and it was made entirely by photographs. The content was created by driving through Aspen in all possible directions and taking pictures every three meters. Then everything was put together in an interactive application where the user, by using a joystick, could select a direction to follow. The program then responded to the input and displayed the appropriate photographs. This application was the very first driving simulator, and it modeled driving a car through the city (Manovich 2001, p. 259).

The second example I would like to mention is Jeffrey Shaw's *Legible City* (1988 – 1991). Manovich considers that this work addresses "one of the fundamental problematics of new media and the computer age as a whole – the relation between the virtual and the real". As in the case of *Aspen Movie Map* this work is also based on existing cities, with three different versions representing Manhattan, Amsterdam and Karlsruhe. The navigation method this time simulates riding a bicycle in a virtual environment populated by 3d letters. The interface is an actual bicycle, where the user sits down and by pedaling moves along the projected 3d streets of the letter architectures. Each 3-d letter corresponds to an actual building in the physical city, with the letter's proportions, color and location being derived from the building it replaces. The texts composed by the letters are drawn from the archive documents describing the city's history. The user navigates around the virtual city by sitting on a physical bicycle and turning the wheel. There are no collisions with the buildings so the user can pass through the letters creating a custom path on the way.

A third example worth revisiting in this context is Char Davies's VR installation *Osmose*. Yet again, the navigation method was modeled on a real life experience, this time Davies' experience of scuba diving. Davis, an experienced diver herself, suits up the "immersant" with a scuba diving-like uniform VR suit, with a head-mounted display, and immerses them into a 3d virtual world with cutting edge 3d graphics of its time. The user had to wear a vest and a headpiece which measured breathing and balance. The data was then translated for navigating the VE. If users leaned in or out, they were moving forward and backwards respectively in the world and if they breathed in and out they were moving upwards and downwards, respectively, as if floating in the ocean. Oliver Grau describes the experience in his book: "Like a diver, solitary and weightless, the interactor first glides out of a grid of Cartesian coordinates into the virtual scenarios: a boundless oceanic abyss, shimmering swathes of opaque clouds, passing softly glowing dewdrops and translucent swarms of computer-generated insects, into the dense undergrowth of a dark forest. Passage from one scenario to the next is smooth, fluid. Whereas early virtual environments utilized portals that rendered transitions abrupt, in the image world of *Osmose* the observer experiences osmotic transitions from one sphere to the next, seeing one slowly fade before it amalgamates into the next" (Grau 2003, 193-204).

As we can see, the majority of the early VR work attempted to simulate real life scenarios like the driving of a car, the driving of a bicycle and scuba diving. *Aspen Movie Map* was really a multimedia presentation rather than a three dimensional space, therefore the navigational structure needed to be thought before it was produced. Unlike virtual worlds where the 3d space is created and then the virtual camera is placed anywhere in the world, when photographs are used then you are limited to their perspective. The choice of simulating a car was also making the experience more realistic and more immersive by transferring the natural flow of the experience from watching it from a car window to a screen.

In Jeffrey Shaw's simulation, the users were going around the 3d virtual cities using a bicycle. It is an action that for most people will feel very natural since exploring a city this way is a common habit. This work is a good example of how navigation as a commonplace under a natural physical activity can aid the immersion in a space. This work has two different and distinct immersion qualities that cannot co-work together. The first one, which applies to the users who know the cities, is getting immersed by identifying buildings and navigating the space by constantly creating expectations of what it is to follow. The mind compares the real and the virtual by superimposing one on top of the other, creating constant identifications and symbolisms. The brain is too busy to get distracted by anything else; therefore it is easier to get into an immersed state. The second way that causes immersion is by making the user interested in the text. The user navigates around forging the required path needed in order to read the archive documents. Suddenly the space loses its meaning as a spatial representation of a city and becomes a virtual "book". The user is again immersed in the space but this time in a completely different way. In order for both immersions to take place the navigational controls must be completely non-intrusive. The flow of movement should come naturaly to the user, not requiring any conscious thoughts to be wasted on navigational controls. Shaw has managed in a way to give navigational guidelines to the users, by suggesting to them a path in order to find the meaning in his work.

Davies' scuba diving simulation, I believe, is till today one of the most innovative ways of interaction with a virtual space. In VR simulations the main problem with an intrusive navigational system is the loss of immersion. In *Legible City* it is much easier to have a suitable control system because the user can only move in 2 dimensions. As there is no up and down movement, the turn of a bicycle handle bar works perfectly. In *Osmose*, Davies wanted to create the illusion of floating inside a VE but at the same time acknowledge the physical body. By making the user wear a cumbersome suit and a big headpiece, the natural movement of the body is restricted as much as possible. The mind being bombarded by the audiovisual experience feels out of the norm and now so does the body. Having achieved this, the next step was to make the immersant forget about the ability to interact with the outside world and concentrate on the immersive experience. They instruct the audience to concentrate on breathing, the most natural and unconscious human action performed by the human body. Suddenly one has to think about breathing, it is not happening unconsciously anymore but rather it has acquired a renewed meaning. Breathing works in combination with balance, both actions demanding enough so that the body and mind will work together, avoiding unnecessary actions that might cause an interruption to immersion, at the same time though not overwhelmingly strong so as to interfere with the audiovisual experience. The combination of subtle forward and backward movement, the attention to breathing and balance moves the user through the environment in a fluid and controlled way simulating exactly what it is claiming, a scuba diving like experience in an unknown virtual world.

The camera as viewed by Tamas Waliczky

When investigating VE and the movement of virtual cameras in an art context, it is illuminating to study the work of the animator and film pioneer Tamás Waliczky. During the last few years, he has created a number of artworks all related to time, space and movement in virtual environments which can be considered quite unique in the field. By insisting on avoiding the cinematic perception and the traditional camera "grammar" of tilt, pan and zoom Waliczky creates his own "universes" reinventing the rules of the audience's perception. Manovich comments on Waliczky's use of camera in one of his essays by stating that "If in cinema the camera functioned as a material object, co-existing, spatially and temporally, with the work it was showing us, it has now become a set of abstract operations. Waliczky's works refuse this separation of cinematic vision from the material world. They reunite perception and material reality by treating the camera and the world as parts of a single system" (Manovich 1998, p.2)

In Waliczky's work *The Garden* (1992) a little girl is portrayed playing in a garden. The artist's aim was to portray the alertness and curiosity of a small child investigating its surroundings, and to evoke the particular sense of affection that children often inspire in us (Szepesi 1995). The perspective of the camera is changed by making the child the center of the world. The objects in the space are getting bigger or smaller depending on the distance between them and the child, therefore as the child moves around the world is transformed. Walickzy called this new type of perception the "waterdrop-perspective-system". "The conventional notion of perspective, dating from the Renaissance, privileges the viewer as the person for whose benefit the depiction of the world unfolds and whose gaze completes the image; the stability of his or her position is mirrored by the fixed vanishing point" (Szepesi 1995). The world is seen as a sphere with the child being the center of its own private universe, acting independent of the viewer who is watching it from the outside. In this piece Waliczky created an unreal and uncanny world which looks like it has being drawn by the same child who inhabits it. The child moves around the space feeling and experiencing the playground, while the viewers see a re-imagination of how a little child feels when is taking its first steps in the world.

In his work *The Forest* (1993) Waliczky wanted to evoke a sense of a never ending forest that has no limits in either of the three dimensions. This is achieved by looping a single black and white drawing of a tree in all three dimensions. The tree is looped firstly in a vertical composition. Then the tree was copied onto a number of two-dimensional revolving cylinders, appearing to pan the camera left and right. Finally the virtual camera was moving forward and background in a circular path. With all three movements together the camera seemed to be moving in all every directions including diagonals, spirals and so forth. With this structure Waliczky alters the whole system of coordinates on which the representation of space depends. As quoted on his website, “The resulting illusion is complete and deeply alarming: the infinity of gaze leads to a total loss of perspective” (Szepesi 1995). Waliczky later on turned this into an interactive installation (in collaboration with Jeffrey Shaw and Sebastian Egner) allowing individual users to explore his world by using a joystick while sitting on a flight simulation chair. Waliczky’s method works brilliantly in displaying the confusing and chaotic feeling of being lost in a forest, especially when viewed from the perspective of a navigational structure. A further analysis of his method and how he handles the three dimensions can teach a great deal on how to create abstract movement in space.

In his computer animation mixed with live video (and the last part of his trilogy), *The Way* (1994), Waliczky depicted three runners followed by a camera in a German village. Instead of having the vanishing point of the camera at its usual place, however, he moved it to the closest possible position next to the view point, inventing the common system of central perspective. Since the viewpoint and the vanishing point are more or less in the same point, every object disappears before it reaches the viewer. The furthest an object is from the camera the biggest it appears. This applies to the runners as well, who since the camera is following them remain the same size throughout acting as a reference point (Waliczky 1994).

In 1997 Waliczky created two animations on the theme of time. *Landscapes* was a piece originally designed for an opera addressing the question of the perception of time. The animation is about a rainy day in a German village, where all of a sudden time is paused. All raindrops are frozen in time and the only living element in the space is the virtual camera which takes the viewer on a trip around the space (Waliczky 1998). In his work *Sculptures* (1997) the artist wanted to visualize how humans’ perception of time differs from God’s perception. In his interpretation, God can perceive seconds, hours, years or even eternity as identical. In *Sculptures* he built in the computer three-dimensional structures, which he named time crystals that depicted everyday movement and gestures such as walking, jumping and weaving. These crystals exist simultaneously alongside each other in space, and a virtual camera (God’s eyes) can observe them from any desired location. Furthermore, by travelling through the time crystals, the camera can reproduce the original movement from a number of perspectives and speeds (Waliczky 1997).

Waliczky attempts to rationalize and display two worlds which exist outside the boundaries of time. In *Landscapes* his work acts as a prequel to “bullet time” (a term which refers to digitally enhanced simulations of variable-speed, popularized by *The Matrix* in 1999) showing the world through a virtual camera in a number of snapshots over time. The world is perfectly still and the viewer enjoys a poetic and peaceful journey that shows no signs that movement ever existed in the space, not even in the raindrops which fit perfectly in the atmosphere enhancing the mood of isolation. On the other hand, *Sculptures* is all about the echo of movement. Even though the “time crystals” are still, the viewer can nonetheless feel the movement associated with them. The virtual camera which moves around them makes them feel alive and as soon as the camera is in an angle where the viewer can identify the portrayed movement or gesture then the time crystal becomes alive in the viewer’s imagination.

The last work I want to mention is *The Fisherman and His Wife* (2000), a 30 minutes long animation based on a German folk-tale. Waliczky based the animation style on shadow-theatre, with each virtual puppet as 2d polygonal forms positioned in 3d space. Puppets have their own light source and background, casting both the light sources and shadows upon other puppets and objects. The work uses the light and the shadows to visualize relationships between humans, reality to virtuality, reality to wishes and reality to dreams (Waliczky 2000).

Waliczky in all of the above projects creates his own systematic worlds, giving them his own rules and structures and visualizes them in his own distinct way. Manovich calls him “a maker of virtual documentaries” and compares him to “an ancient cosmologist” (Manovich 1998) .The camera and navigational system, as well as space and time, exist together complementing each other creating unique universes with distorted physical properties and out of the ordinary visual perceptions. Waliczky’s work demonstrates the importance of creating a unique camera view point and navigational method for each project depending on what the architect of a VE wants to portray. His use of unconventional camera structure was not only avoiding standard Hollywood methods to differentiate his work, but rather it was an integral part of the experience. They viewpoint inside the world was not only showing content and actions inside the space but rather shaping them by giving them a different visual identity that could only be rationalized when viewed through these camera structures.

Camera Structures in Interactive Virtual Environments

During the 90’s VEs have become common place in entertainment, ranging from games, films, simulations, architecture, visualizations and social networks. For the next part, I will distinguish between a number of applications and their most common navigational structures. The rise of gaming platforms and the advancements of technology made 3d worlds accessible to home users. During the early 90’s computers were powerful enough to handle simple real time 3d polygonal graphics. The First Person Shooter (FPS) genre was born in 1992 with *Wolfenstein 3D* (id Software, 1992) and became mainstream and popular the following year with *Doom* (id Software, 1993) (Fig.1). In the FPS genre the user is experiencing the action through the eyes of the protagonist, in a first person perspective.

Fig.1 Screenshot of *Doom* (1992).

Both games are fast paced, where the user is in control of the avatar who is travelling along endless corridors killing enemies (Nazis in Wolf3d, Alien monsters in Doom), collecting new weapons and power ups. The world architecture, the landscapes and buildings in the virtual environment are mostly repetitive giving the player no reason to stop and admire. The essence of the game is to move forward and complete the stages of the game quickly by killing enemies. The hero is never fully visible; the user can only see a hand resembling a prosthetic limb which acts as an extension of the body of the player.

Around the same time of the early 1990s, coinciding with the sales of CD-Rom drives, two more influential puzzle games have been released, utilizing the extra storage space of the new medium. *The 7th Guest* (Trilobyte, 1994) (Fig.2) and *Myst* (Cyan, 1993) (Fig3). *The 7th Guest* is a combination of pre-rendered 3d graphics and full motion video, whereas *Myst* is a series of pre-rendered images and animations. Both games have a slow rhythm where the user is welcomed to navigate slowly, absorbing the atmosphere and the beautifully crafted worlds. Navigation is done by clicking the mouse and the camera moves to the next pre-defined place in space. There is no complete freedom in movement but rather fixed points of interest connected either with pre-rendered animations (*The 7th Guest*) or by jump cuts (*Myst*).

Fig.2 Screebshot of *The 7th Guest* (1993). Fig.3 Screenshot of *Myst* (1993).

By looking at the specific tasks one has to accomplish in the games, the role of the navigational structure becomes clear. In the FPS genre there is much more freedom of movement because the environment is there just to host the enemies. There is limited exploration in each part of the world but rather the player must find its way around the space in order to move to the next stage. There is a constant flow of forward movement (with the occasional backtracking if one is lost or missed an important item such as a key) and the space is just another obstacle on your way. On the other hand, in the puzzle genres the space is there to be explored. One cannot move forward in solving the quests until every scene is thoroughly investigated. Stopping to think, find and analyze hints and ponder at the beautiful scenery is what the game is all about. Also, the puzzle games cannot really immerse someone unless there is a narrative. In the FPS genre immersion comes because of the fast pace and the fear and danger of what is lurking in every corner. One wrong move and you die. This urgency is missing in the puzzle genre and is being replaced with a narrative. The world is immersive because there is a reason for the hero to be there and the player is there to follow it through. If *Myst* was nothing more than a placeholder for a number of puzzles without something to connect them it would not have become as successful, with a great many spin offs of sequels and books, further building onto the narrative. Therefore in order to devise a suitable navigation system for this game it was necessary to think of a technique which would point the players in the right direction. The world is hugely vast and if one had to explore the world to find a hint for a puzzle using the same navigation system as *Doom* it would take far longer risking a shift of balance from enjoyment to frustration. The game cleverly pushes the players to the appropriate points of interest, at the same time making sure that the world is displayed from an optimal camera view to show off its aesthetic qualities.

Even though both the nature of the game and the involvement of the spatial fictions of the two genres are completely different, there is one common element of similarity. All four games are spatial journeys. The user must navigate the space in order to complete the story. There is no time urgency, time does not matter. The journey will last until the players navigate the environment and complete their quests, that being either kill all the enemies or solve all the puzzles. As Manovich states, "In *Doom* and *Myst* – and in a great many other computer games – narrative and time itself are equated with movement through 3-d space, progression through rooms, levels, or worlds" (Manovich 2001, p. 245).

All the games mentioned above use a first person perspective camera view in order to suggest that the hero is actually the player and the player inside the virtual space. The FPS genre has undergone a large technological and methodological evolution during the last twenty years but most of the navigational structures remain the same. In games like *Crysis* (Crytek 2008) the user has now the ability to look up and down as well as left and right. When the camera faces downwards towards the ground the hero's legs are visible and animated increasing the realism of the game. In the first iteration of the genre, the hero was merely a virtual camera placed inside a VE at the height of the eyes. Newer games follow a different methodology. Instead of placing just a virtual camera, they import a 3d model of the hero and they animate the model and his/her behavior in the space. This would also entail up and down breathing movements while running, leaning sideways, ducks and all of their follow up secondary movements. An example could be as the avatar approaches a wall, he might extend his hand to push the wall to slow down his momentum. The virtual camera is then placed and oriented at the eyes of the character, looking out at the world. In theory, it is just an FPS camera but in practice if feels more immersive, exemplifying perhaps the varying degrees of visual immersion. Furthermore, as games are striving to make their heroes more believable as characters, they are moving away from the concept of the player being the nameless hero and moving more towards the concept of the player assuming the role of a developed character. This way more cinematic cut-scenes are included in the game showing the progression of the narrative and the development of the character.

Second Life (Linden Labs 2003) is using a third person/observer camera. The avatar appears at a distance in front of the screen and moves around in the VE with the camera following closely behind. In this camera view mode, as Morie suggests, "the avatar appears to be in the space occupied by the person's mental construct of where they are in the VE" (Morie 2007, p.132). This is a common format for a lot of adventure games since it can put the players right in the midst of the action, making it easier for them to calculate distances, perform the required moves as well as showing them in full galore the possibilities of their action heroes. As the field of view of the user around the player is much broader, the navigation in the VE can be easier if the camera is set up correctly. In a number of free roam games this method of camera view creates problems since often buildings or other environmental constructs of the VE end up between the user's field of view and the avatar. This can be especially frustrating in fast paced action games where a few seconds of game play interruption can result in the player losing the game.

A final camera view system that I would like to mention is the cinematographic camera. This has been used in a number of games with great success. In order for this method to work successfully the game space is divided into sections or rooms. Each section has a pre-defined camera optimized into showing the player the action and the points of interest of the section. Navigation-wise this works really well because the player has no intrusions of any kind. This kind of camera can also increase immersion since the creators usually spent a lot of time to give to a game a cinematographic feel thus giving the players the familiarity of a heroic Hollywood movie while they are actually in control of the character. An example of cinematographic cameras can be viewed in the following 2 pictures from *God of War 3.* In this game, the player is controlling Kratos, a Spartan Warrior who rose to the throne of Ares by killing him and becoming the new God of War. The game creators, wanting to demonstrate the immensely difference in physical scale between humans, Titans and environments, created models of greatly varying sizes. In order for the game play to be enjoyable, however, the player needs to have a constant spatial awareness of the avatar she is controlling.

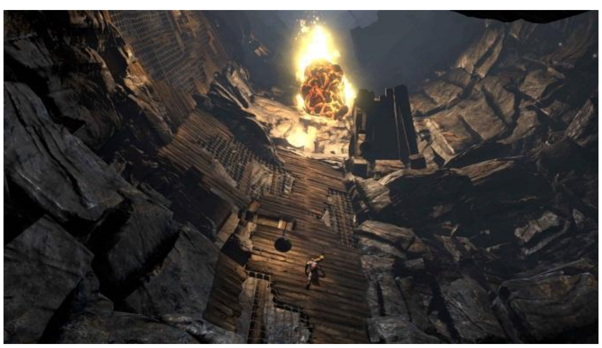


Fig.4 Kratos trying to escape the Underworld (*God of War 3*).

Fig.5 Kratos squashed by the Titan Chronos (*God of War 3*).

As this was very difficult to achieve with conventional free roaming cameras, the developers created scripted alternating camera scenes shifting between each other, depending on where the avatar is at any given time. In the first illustration (Fig.4) Kratos is climbing the walls of the underworld in an attempt to escape, trying to avoid falling volcano rocks while player must guide the avatar left, right and up accordingly. The camera here is kept at a distance to show the player the falling rocks. As soon as Kratos climbs up to a pre-defined point where the player cannot view the action from an optimal view, the camera will zoom to a different angle. In the second illustration (Fig.5), the Titan Chronos is squashing

Kratos in his fingers. Kratos is tiny compared to Chronos and this camera angle can demonstrate this perfectly. The player is still in partial control of Kratos here, even though Kratos cannot really move. The player needs to press a button repeatedly to prevent Chronos from closing his finger and as soon as he/she succeeds the camera zooms to a closer angle to continue the normal flow of the game.

Most art works avoid having a third person or cinematographic camera because unlike games there is not enough time for the user to gain a familiarity with the character. Forcing the user to experience the work from the perspective of an avatar might feel disconnecting and uncanny, with too many wrong associations. Avoiding a humanoid figure might be a good solution to minimize that problem but still the conceptual idea of the application can vary greatly depending on the camera view. The game *Flower* (thatGameCompany) is an example of a game that uses a third person camera but still manages to avoid disconnection. The player is in control of the wind and some flower petals, navigating around rural environments, interacting and shaping the space. The wind and petals do not feel like a separate entity from the player but rather the player feels swept by the wind along with the petals through the virtual space.

Fig. 6 Screenshot of *Flower* (ThatGameCompany 2009).

Total Installation

When architects of virtual spaces start their construction, they need to set some boundaries. Virtual space is infinite in all 3 dimensions. When one is creating a VE for a movie, an animation or a non-interactive medium then the director or the designer has control on what the virtual camera sees and what is displayed to the audience. This however is not the case in an interactive work. Each created space has boundaries and beyond those boundaries there is nothing. Users should not be allowed to cross the boundaries as this will result in loss of immersion and a quick loss of interest. Furthermore, there are certain places in the VE where the user must pay special attention. The architect must carefully orchestrate a way for the users to semi-control the path and freedom of navigation in order to offer them full enjoyment, a principle which works paradoxically with the constant effort to create open ended sandbox games, where the user has full control and freedom.

Game design allows a variety of ways to tackle these issues. Some games use maps which show the boundaries of the world, the position of the user and the destination. Others have a compass with an arrow to show the direction of the next checkpoint. Roads have signs; wrong ways are blocked by fences or objects, a non player character who accompanies the player guides the way. These tricks work well because the users know where they should head to but they are also free to roam around and do as much exploring as they wish.

Ilya Kabakov, the Russian-American conceptual artist has addressed similar issues in his concept of “total installation”. Kabakov’s installation work revolves around constructed spaces, like rented apartments or school rooms, which he makes to look like “emptied” stage sets or real places where something has taken place and then they were left behind almost as if they were plastinated in space. In his 1992 work *The Toilet,* he creates a replica of a provincial Soviet toilet which has been turned into a two room apartment complete with a table, glass cabinet, book shelves, a sofa, dirt dishes, toys, paintings and a clock and radio. All of the objects are placed alongside the open toilet cohabiting in unison with them. Svetlana Boym, a theorist and media artist, discusses the installation by saying “Kabakov’s toilet does not offer us the conventional satisfaction of a single narrative, but leave us at a loss in a maze of narrative potentials and tactile evocations. What makes it obscene it its excessive humanness and humor… The toilet is embarrassing, not shocking. It does not contain the excrement of the artist, but his emotion… The black hole of the toilet might be equally mystical, but its power lies on the border between art and life” (Boym 1999, p.5) Boym’s comments match well Kabakov’s ideas as expressed in the introduction of his lectures “They [the viewers] are simultaneously both a ‘victim’ and a viewer, who on the one hand survey and evaluate the installation, and on the other follow those associations and recollections which arise in they; they are overcome by the intense atmosphere of the total illusion" (Kabakov 1995, p. 256).

Kabakov’s elaborated methodology guides the viewer into immersion by creating an enclosed space with carefully selected proportions, colors and lighting and completely isolating it from any external distractions (ibid). He invents strategies in creating a well crafted path through the space that does not stop the freedom of the viewer but does prevent the feeling of being lost and bored. Such a space is created by constructing corridors with objects, by obstructing passages and even controlling the navigation and pace of the viewer by placing text or other objects of interest at particular points in space. He calls this installation type a “total installation”. He is a firm believer that an installation needs to constantly keep the attention of the viewer “The reaction of the viewers during their movement through the installation is the main concern of the designer … The loss of the viewer’s attention is the end of the installation” (Kabakov 1995, p. 162). In his work *The Man Who Flew into Space from his Apartment* Kabakov created a hero who did the impossible and flew alone into cosmic space. In the spaces where the installation was presented, the audience viewed a scene that seemed to have taken place just before their arrival. The room was filled with Soviet propaganda and posters. All that remained in the room were the bed, the table scattered with drawings, the catapult and a hole in the ceiling from which light was shining through.

Fig. 7 Screenshot of Ilya Kabakob's The Man Who Flew into Space from his Apartment. (c) Ilya Kabakov, 2006.[7]

Manovich claims that a “total installation” can be considered to have two identities. It belongs both to the plastic arts such as painting which are designed to be viewed by an immobile spectator but also belongs to time based arts such as theatre and cinema (Manovich 2001, pp. 266). The same can be said about virtual navigable spaces. The majority of the VEs are designed for entertainment, thus a special attention is paid in giving them an aesthetics that are meant to provoke emotional responses from the users. Kabakov

[7] Uploaded by Ilya Kabakov to the website http://www.orbit.zkm.de/?q=node/19 on 15/3/2006.

believed that when users enter an installation, they carry with them experiences which, combined with spatial stimulations, produce emotional responses. “Here installation art bestows an unprecedented importance on the observer’s inclusion in that which they observe. The expectations and social habits that the viewers takes with them into the space of the installation will remain with them as they enter, to be either applied or negated once they have taken in the new environment “ (Kabakov 1995, p. 257). Ultimately, the only things viewers can be assured of when experiencing the work are their own thoughts and preconceptions and the basic rules of space and time. All else has become a medium in the artist’s hands. One further common distinction between the two mediums is the time-space structure. Both mediums are spatial journeys, thus the structure is created by the movement and the pace of the visitors through the space.

Games, just like the majority of movies and books have characters, a narrative and a flow that guides the players through a journey. When game designers create games, the whole concept of enjoyment is making the players assume the role of either a different and more enjoyable version of themselves (like in *Doom*) or to assume the role of someone else (like in *Tomb Raider*). Even though they are, like installations, spatial journeys, in my opinion there is little time and opportunity to reflect and apply personal experiences as most of the time players are trying to improve the character they are controlling. In games like *Doom*, it’s all about finding the next and more powerful weapon in order to kill more aliens, whereas in Role Playing Games (RPG) like the *Final Fantasy* series (Square Enix 1987 - 2010) or *Baulder’s Gate* (Bioware 1993) it gets even more complicated with players having to modify their characters choosing from a vast array of options. This does offer a personalized experience to the player but one that is controlled by the game designer.

On the other hand as discussed before, in VE in art installations and interactive performances usually there is no character development (as referred to in games), no narrative and no avatar. As a rare exception, New York media artist Toni Dove has done experimentations with responsive media by attempting to use visual cues to “include the entire body as a haptic interface creating a more nuanced somatic connection to narrative experience. This involves a dismantling of narrative and cinematic language to arrive at a different method of story constructions” (Dove 2005, p.107). In her work *Artificial Changelings* (1998), an interactive narrative switching between a 19th century kleptomaniac and a futuristic encryption hacker, the viewer could move a character’s body, generate speech and alter or create a soundtrack by standing in front of the screen. In addition, floor pads could be used as triggers to dissolve between different video spaces organized according to levels of intimacy with the character. By standing close to the screen the user is controlling the character’s head, the middle pad gives access to the conversation tree and the far pad offers an alternative state of existence, a trance/dream state. A further smaller pad behind the three main ones, allows the viewer to move back and forth between the two centuries of the "story" at will (Dove 2005, p .108). Birringer, in his review of *New Visions in Performance: The Impact of Digital Technologies*, found Dove's concepts captivating but when he witnessed her installation he failed to notice "any of the subtleties and enchantment ("trance-like state" of being immersed, lost in space and time) that she claimed" (Birringer, 2004, p.3). Instead, he saw users trying to control the movie character with clumsy gestures that mirror the gestures of the movie character.

Navigation Interfaces in Art Works

Frances Dyson, in her introduction to *Sounding New Media: Immersion and Embodiment in the Arts and Culture*, proposes that associations made between seeing and being, which is the principal assumption of FPS cameras, has significantly shaped the development of Western thinking. Vision, she says "becomes the ground for all objectivity, certainty and inspiration" (Dyson 2009, p. 13). She believes that the actuality of sight has been transformed into an "ideology: the individual becomes the center of the world, always looking outwards, one's gaze like god rays scanning, naming and colonizing the universe" (Ibid). This ideology is reinforced through the front perspective of VR, not only because of the position of the screens but also the cultural associations between vision and modernity. Looking ahead, she continues, is "metaphorically equated with enlightenment, evolution and progress – read technological invention; whereas looking back, or looking behind, is considered regressive, 'backward,' going against not only the telos of Western civilization but the species itself" (Ibid). FPS games are always in constant motion, urging the player to constantly move forward explore new areas, uncover new weapons, discover more mysteries and solve more puzzles. The same applies to immersive VR environments where the image surrounds the viewer completely blocking out the external environment. Dyson comments how "a person's subjectivity is then collapsed into a single point of view – the virtual world is nothing other than what it is, literally, in front of the user, and it is 'navigated' rather than simply viewed by the viewer" (Dyson 2009, p.14). Moving forward therefore, wrongly becomes an expression of progress, a desirable state denoting the aspiration of further exploration, all in the sake of feeding the eyes' unsatisfied hunger for stimulation.

Dyson identifies that a number of artists and new media theorists attempted to challenge the disembodying effects of VR, but praises Char Davies (for her work on *Osmose* and *Ephémère)* who also challenges this frontal perspective and the aesthetics of moving forward. Davies commenting on her choice of camera for *Osmose* says that her work is meant to "…reaffirm the role of the living physical body in immersive virtual space as subjective experiential ground." She continues furthermore by saying that "this type of (non) imaged embodiment can allow one to remain in touch with their inner conception of their own native, imagined self. This is the underlying premise for my own virtual environments which use this first person point of view" (Davies 1998, p.2). Dyson appreciates Davies' work not only because being closely tied to her interest in immersive aurality, it disrupts the object and the eye's acuity through the use of translucence and transparency but also because of her navigational interfaces which is based on breath and balance.

In a performance context, a number of artists in the recent years have worked with innovative interfaces to control the virtual space. In 2006 Birringer and his team worked on *See you in Walhalla (2006),* a streaming telekinetic performance event hosted and performed simultaneously in three cities, Athens, Sofia and Amsterdam. In *See you in Walhalla* the performer is placed in front of a 12m x 3m projected image, split into three screen, where she goes through a journey taking place in an imaginary cityscape that is composed of real and virtual urban imagery. The performer, Ermira Goro, dances the scenes of the game world choreography wearing 12 sensors on her body. Those sensors allow her an immediate and direct relationship to the virtual world in which she literally moves and navigates. Just like an avatar that a player would navigate in a game, the dancer here is navigating her character into the digital world by using body movements, and she is also responding to the programmable interactions she does not control, such as the appearances of the other players streamed in from the webcams in Amsterdam and Sofia (Birringer 2006). This is just one of the productions involved with wearable sensors which were undertaken by Birringer and his team, two more (*Ukiyo (Movable worlds*) and *Suna No Onna*) will be analyzed in much greater detail in subsequent chapters.

Intimate Transactions (2005), an award winning interactive network installation by the Australian group Transmute Collective, not only has a most unusual kinetic interface but is also philosophically inspired by ecological ideas. The theme of nature, translucent landscapes and life worlds seem to be a common area touched with immersive art, a trend that can be noticed also from *Osmose* going all the way to the 3d film *Avatar,* directed by James Cameron. Birringer describes the installation as "a networked transactive environment, involving telematics performances that jointly catalyze the behaviors of creatures in a virtual ecology" (Birringer 2008, p. 207). He goes on to describe the physical/virtual interface as "unusually thoughtful, sensual, and challenging from a synesthetic perspective, as the Bodyshelf combines various motor-sensory, tactile, and haptic dimensions" (Ibid). The Bodyshelf interface could detect weight balance shifts and well as various types of back pressure, produced by the user leaning on it. Even though the main focus on the mediating world was still visual, Birringer observed that the transitive sensory relation to the screen was rather complex as the user had to operate in the virtual space through the soles of his/her feet, shoulders and spine. The scope of the installation was two users, each in a separate secluded space which could be in the next room or in another country, co-existing through the networked physical interface in an evolving virtual world. The users had to in fact collaborate in order for the virtual world to survive. The users could move their avatars around the space, connecting with elements which they could be picked up and given to the other user, keeping a balance in the ecosystem.

Building a Navigational Structure for an Interactive Performance

In this section I have investigated a number of art works and games, commenting on their navigation structure and interface design. It is obvious that a number of past examples exist in the interactive digital mediums such as games and installations, there is however very limited scholarship on interactive 3d performances aimed towards an audience. As there is no past example of a performance that includes an interactive 3d space, it is very difficult to theorize what it would be and what would not be interesting for an audience to watch. Since I consider the VE as a navigational space, I shall investigate the possibility of producing immersion through the VEs content and navigational structure, rather than purely sensorial stimulations which would require a much more elaborated physical set up, usually more suitable for an individual rather than an audience.

Movies immerse audience by involving them with characters and stories; games immerse them by either taking them along on a character's journey or by actively making them construct and improve their characters. In installations and performances characters and stories cannot be included since there is no time for the user or audience to develop any kind of relationship or identification with them, and furthermore they will probably add very little to the sensorial experience they aim to invoke. As a VE is a space designed to be navigated, and that navigation will be purely performed by the dancer, a question needs to be raised on how the audience will find any sensorial stimulation from the event. Taking computer games as examples, with the lack of an interesting story or character, the only way for the user to get immerse is by means of ludology (immersion caused by elements of playing the game, such as leveling up your character) , a concept which of course cannot be applied on an audience. It will be interesting to consider the possibility of using Kabakov's total installation concepts with the aim of invoking immersion but that would require for the audience to compose their own spatial narratives. "Ultimately, the only things a viewer can be assured of when experiencing the work are his own thoughts and preconceptions and the basic rules of space and time. All else has become a medium in the artist's hands" (Kabakov 1995, p. 257). As with all spatial narratives, audiovisual cues from the projected environment are mixed with the thoughts and preconceptions of the audience forming a collaborate result of sensorial stimulations. It is therefore essential that when the space is being designed to take this into consideration by (1) including content which is abstract enough to provoke stimulations and (2) to display it in an optimum way.

Susan Broadhurst has identified heterogeneity, indeterminacy, fragmentation, hybridization, and repetition as prominent aesthetic features within the digital domain (Broadhurst 2006, p.142). Even though she is mostly referring to fast changing multi-color projections as she was evaluating Palindrome's "shadow" performances, these features can also be subtly implemented in content creation and navigational structures of 3d spaces, in order to promote the audiences' active participation in the production of meaning. The 3d models in the space could appear to lack uniformity; they could look fragmented and at places poorly defined, in different varieties and forms, and repeated over time. I do not suggest here that the 3d models should actually be created with those parameters as this would limit their potential uses, but rather use navigation and rendering techniques to make them appear so. Just as in Waliczky's work, the camera should not only be showing the content inside the virtual world but rather give it a unique visual perspective that is integral to the experience. Even though the camera structure needs to be project specific, a number of common techniques should be present. The camera should very rarely stay still as this would reveal too much of the environment giving the mind enough time to place it in context, thus removing the element of the unknown which provokes curiosity. The camera should not be kept at optimum distances for the eyes to identify what they are seeing. Zooming too close to the object or showing it from a distance might be desirable as to keep the shape of the objects fragmented and poorly defined. Dark lighting and/or fog could also be employed in order to enhance the effects, creating an atmosphere of eerieness and mystery. The camera could also cover long distances, identifying that the same fragmented shapes exist in a variety of sizes and forms, all at the same time enhancing the curiosity and anticipation of the audience. It comes as no surprise as to why a number of installations and art works follow the theme of nature (such as *Osmose* and *Intimate Transactions*) as the exact abstract characteristics can be identified in abundance in nature.

This methodology raises a number of questions which could initiate discussion. Firstly, how would the performer enact the interactive navigation? Does she/he need to be in charge of it? Or can the audience accept that the system or an external agent such as the designer is acting as the real time director, showing them the space that the performer is embodied in? Even though that is a decision that needs to be decided on a project specific level, I would argue that not only the performer does not need to be in charge of navigation, but even better, the system needs to completely undertake the task. During the staging of a real time digital performance with 3d worlds being projected as 2d images, there is always the issue of proximal and distanced relationships between the performer in the real space and the virtual world projections. There is a mixed reality setting where the audience are either watching from their seats, or in the case of a choreographic installation like *Ukiyo – Moveable Worlds*, being involved by feeling, hearing, touching, smelling, sensing and intimately co-living the "system environment". The performer is part of a hybrid world where his or her physical presence is shared within the virtual space mediated through technology, which is an essential part of the experience. The hybridized word is partly physical and partly technological constituting a system of collaboration. As we are moving away from pre-rendered linear worlds and into livable ecosystems and life worlds, both the content of the virtual world and its visual representation should be self-initiated and independent. VE creators need to move away from building worlds which are constantly relying on the performer's input as that constitutes a performer using technology to create a world and not a performer co-existing with an intelligent system in a mixed reality environment.

Mixed Reality and 3d Space

The Systematic Universe

In order to conceptualize what is the projected 3d virtual space firstly I shall try and look at different definitions theorists have given such space in the recent history of art theory and digital studies. Erwin Panofsky, one of the founders of modern art history, in his essay “Perspective as Symbolic Form,” presents us with two different views. As Lev Manovich states in “The Language of New Media”, the first one originates from the time of the Greek antiquity, postulating that space is discontinuous and aggregate, whereas in the second view, originating in the late Italian Renaissance, space is infinite, homogenous, isotropic and with ontological primacy in relation to objects. In short, in the first view there is no totality, unlike the second view where the space functions as a system (Manovich 2001, p. 254).

Even before Panofsky, Alois Riegl in his 1901 work *Die Spatrömische Kunstindustrie* categorized space through two distinct understandings, which he named “haptic” and “optic” perceptions. In the haptic perception objects exist as independent discreet entities, where in the optic they function as unified objects in a spatial continuum (Manovich 2001, p. 254). So where does the virtual space fall in regard to those two categories? Or to raise another question, should the virtual space fall in either of those two categories at all? Manovich argues that a virtual space has not evolved enough to be considered as a systematic universe and it does indeed fall in the first category. His argument consists of three points, and I will proceed to analyze each one with today’s standards.

He firstly points out that in a virtual space there is no “space-medium” – an environment in which objects are embedded and the effects of these objects are happening on each other. The idea originated from Russian writers and artists and it is referred to as *prostranstvennaya sreda*. The Russian philosopher Pavel Florensky defined it as “The space-medium is objects mapped onto space… We have seen the inseparability of Things and space, and the impossibility of representing Things and space by themselves” (Manovich 2001, p. 255). The idea was further supported by a group of modern painters (Seurat to Giacometti and de Kooning) who tried to move away from the concept of empty space filled with distinct objects. Instead they prefer to characterize it as “a dense field that occasionally hardens into something that we can read as an object” (Manovich 2001, p. 255). Manovich claims that this concept has not been discovered by mainstream computer graphics yet.

The second point he makes is that 3d virtual worlds are nothing more than a collection of separate objects which are not related to each other. He explains how 2d games and animations were made, where the actors had no way of interacting with the backgrounds, and argues that even though now that technology has evolved enough for real time 3d rendering to be possible, still, there is no element of totality.

Finally, the third and final point he makes is that a virtual world, most commonly a game world, is never a continuous space. He mentions the game *Doom* as an example and explains that the game designer created a series of discrete levels, which are made by a series of discrete rooms, corridors and arenas. Therefore the space cannot be conceived as a totality.

It is quite interesting to see how technology has evolved since Manovich wrote his book. Currently when one is looking at the technological evolution of virtual worlds, one needs to refer to computer games. The concept of the space-medium implies that the objects existing in the space need to have an effect on each other. With the implementation of physics and weather simulation in modern game engines, we have concepts such as gravity, wind, rain and global illumination all of them acting on all objects in the scene. Furthermore, physics engines apply Newton's three laws of motion (or any custom made version of them) throughout the space; therefore if one object in the scene collides with another, there will be transfer of force between them. Global illumination covers the area, realistically portraying where shadows fall. Snow falls on all objects and objects are covered with snow in real time. One can therefore argue that since objects do in fact have an effect on each other, and as well are all under the "umbrella" of a system of simulated rules, therefore this can constitute a space-medium.

Moving onto the second point, as Manovich says, 3d virtual spaces are constructed purely of distinct 3d objects. That would make one think that if a room is populated with 5 objects, the user can only interact with just 5 objects. That is indeed a wrong assumption. Once more, contributed to physics and simulation engines, an object is no longer a unique rigid construct. A rock, for example, dropped from a high enough distance can shatter into pieces, and a table when it is hit can break in half. As these reactions are not pre-defined and rely on simulations, if you take the same rock and drop it twice from the same distance most probably the shattering effect will be different. Everything is simulated in real time. If you kick a table with enough force in the center, the table will break in two. If you kick its leg though, just the leg will break off. So even though a 3d space starts with a fixed number of 3d objects, once the objects are in the space they can be manipulated further just like in a physical space.

The last argument that Manovich makes, is the one about the continuity of the space. Even though it is true that most game designers design their spaces as discreet spaces, the only reason that is done is for simplicity and towards avoiding technical limitations. A huge game world is possible to exist; the main reason virtual world designers do not do it, it is because such design would just take much longer to load, thus interfering with the enjoyment of the user.

I would argue that technology has greatly changed since 2001 when Manovich wrote his book; therefore it might be necessary to re-think his conclusions. Virtual spaces, both online and offline, have evolved.

Even though the rules that have extended to cover and govern them are nothing more that algorithms and codes, they still function and simulate totality. 3d objects are not individual unconnected entities any more but they function together in unified spatial continuum, all of them sharing the same space, the same time and obeying the same physical rules.

Hansen's Mixed Reality

Myron Krueger, one of the original pioneers of virtual reality and interactive art, said about 3d space: "Three dimensional space is more, not less, intuitive than two-dimensional space…Three-dimensional space is what we evolved to understand. It is more primitive, not more advanced than two-dimensional space" (Krueger 1993, p. 161). As beings facilitating their embodied state in 3d space, existing, navigating, behaving and interacting in 3 dimensions can be considered part of our nature. Making a shift of perception however from a real environment to a virtual one does not come without its challenges. Krueger, firmly arguing against the ocular centric views of Western contemporary society, insists that what really counts towards a more immersive experience is the degree of physical involvement and not so much the 3d scenery (Turner 2002, p. 2). Oliver Grau characterizes the connection with the virtual in the following manner: "No longer a wholly distinct, if largely amorphous realm with rules all its own, the virtual now denotes a 'space full of information' that can be activated, revealed, reorganized and recombined, added to and transformed as the user navigates…real space" (Grau 2003, p. 247). A 3d virtual interactional space would therefore need to act as another realm of possibilities for the performer alongside the real space.

In this section, firstly I will explore the theoretical aspects of how such a virtual 3d space can come into existence, how it can form a connection with the performer and aid embodiment, evolve, facilitate change, become part of the performer and consequently part of the performance as a whole. I will explore theories from Maurice Merleau-Ponty and Mark Hansen and try to explain how Merleau-Ponty's body-image and body-schema concepts can be considered and applied when one is designing a virtual space aimed for real time interaction.

Space in the digital realm always starts clean. There are no rules or laws governing the space and it is completely unaffected by external or internal influences. This is the only time one can claim that this world is complete. Digital code is a system of repetition. In order for the world to exist the system needs to be in a constant flux. When the designer is creating the space, the first step in creation is "starting" the universe. This put the computer into a mode of constant loop that searches for processes to compute. A 3d world in operation mode, without any content, is a like a perfect circle stuck in an endless uninterrupted and unchallenged loop. As soon as the architect starts instantiating virtual constructs and rules in the world then this purity is lost. The system, while looping, passes through and analyses, compares and processes every single element that comes to exist in the space. The space now becomes a world and it is no longer complete; the system is now expecting an input. This input can be anything from a person pressing a button, movement in front of a camera or an audio signal from a microphone.

Brian Massumi in his book *Parables for the Virtual* argues that the digital realm has potentiality but what really produces the possibilities (which he calls inventions) is the analog. “Whatever inventiveness comes about, it is a result not of coding itself but of its detour into the analog. The processing may be digital – but the analog is the process. The virtuality involved, and any new possibility that may arise, is entirely bound up with the potentializing relay. It is not contained in the code” (Massumi 2002, p. 141). This is an interesting statement when applied to interactive art and perhaps it should be mainly attributed to the fact that the system was designed to be interfaced with the analog. In this case it encompasses inputs which were not produced by a digital source, or more specifically inputs which were caused by an external factor such as actions in the physical space. What I will try to argue though in the second part of this section, is that for the virtual world to leave a lasting impression, relying completely on the analog to produce “inventions” might not be enough. The virtual world should have continuity and work both together and independently from the person interacting with the system. Here I am not referring to the underlying code that is used to run the system at its original uninterrupted form, which obviously runs without any input from the analog, but rather to the code which turns the space into a world and is responsible for creating its visible realizations.

The French phenomenological philosopher Maurice Merleau-Ponty views the phenomenal body as our primary access to our reality. Even though there are several approaches to phenomenology, Merleau-Ponty views the individual and the world not as part of a whole but rather as separate entities subjected to the phenomenon of the individual. Hansen, in his book *Bodies in Code* celebrates and expands this idea to the domain of new media art (Hansen 2006). He argues that technologies can change or enhance our sensory experiences consequently affecting our view of embodiment. Wanting to move away from what he calls “the clichés of disembodied transcendence” Hansen envisions a world with a fluid interpenetration of the virtual and the physical realm (Hansen 2006, p. 2). Deriving his theories from Merleau-Ponty’s notion of “reversibility” and the idea that the body has an ability of inverse sensorial duality (for example, it can see and can be seen), the main focus of Hansen’s book is how vision needs to be combined with touch in order to shorten the gap between ocularcentrism and a body’s inherent simultaneous multi-sensations.

Going a step further, Hansen argues that “Motor activity – not representationalist verisimilitude holds the key to fluid and functional crossing between virtual and physical realms (Hansen 2006, p. 2). According to Hansen the success of generating compelling virtual experiences comes not from representational aesthetics but rather by simulating tactile, proprioceptive and kinesthetic sense modalities. Expanding on a theme addressed in his previous book *New Philosophy for New Media,* Hansen couples the sense of reality with touch and the perception of spatial depth and argues that by including bodily movement the formula has enough elements to “synthesize” the other senses; therefore perception is transformed into experience. (Hansen 2006, p. 180) He calls this notion Mixed Reality and defines it as “The eschewal of representationalism and embrace of a functional perspective rooted in perceptuo-motor activity” (Hansen 2006, p. 3).

Hansen, in his first chapter in *Bodies in Code* defines Merleau-Ponty’s body image and body schema as “…The body image characterizes and is generated from a primary visual apprehension of the body as an external object, the body schema emerges from what, with autopoietic theory, we have called the operational perspective of the embodied organism” (Hansen 2006, p. 39). Merleau-Ponty offers an account of the body schema as “a flexible, plastic, systemic form of distributed agency encompassing what takes place within the boundaries of the body proper (the skin) as well as the entirety of the spatiality of embodied motility. In other words the body image refers to how the body is represented whereas the body schema refers to the organism within, which is caused by movement and subsequently causes it” (Merleau-Ponty 2005, pp. 85 -131). As Hanson phrases it: “Because it is responsible for linking proto sensory bodily sense (proprioception) with perception and motility the body schema is a source of embodied potential (Hansen 2006, p. 42).

In the first generation of interactive media works, where a performer or a member of the audience interacts with a direct one-to-one relation to the projected image, the visualized body image drives the body schema. The system will only respond interactively after it is being offered an analog signal, usually in the form of movement from the interactor. All subsequent movement, even though originating from the body schema, is a result from the immediate visual or audio stimulation derived from the body image, a process which in dance performances can be considered as causing “disembodiment” of dance (Fig.8). In dance works where a second generation interactive system is in place, the visual representation of the body image is often removed completely. The interactive audio-visual feedback is more subtle, taking more time to develop, and it does not directly relate to the body image. It is perceived more subtly, therefore it is being “absorbed” by the body schema at a slower rate, allowing the dance to get *influenced* but not *directed* by it. According to Hansen this offers a disconnection of the fundamentally motile body schema from the fundamentally visual body image, and now the viewer (or performer) is technically enabled to utilize the excess of the body schema over the body image to increase her agency as an embodied being (Hansen 2006, p. 20). He calls this "body-in-code" and defines it as: "A body submitted to and constituted by an unavoidable and empowering technical deterritorialization – a body whose embodiment is realized, and can only be realized, in conjunction with technics" (Ibid). Therefore, in Hansen's mixed reality space, the performer is using technology able to exist and interact with more than one realm. As performers dance in this space, they have the ability to activate, reveal, reorganize, recombine, add and transform the space. Their actions are limited only by the rules of the realm they interact with. Assuming that one of the realms is our physical space it is for example limited by gravity, Newtonian laws of motion etc.

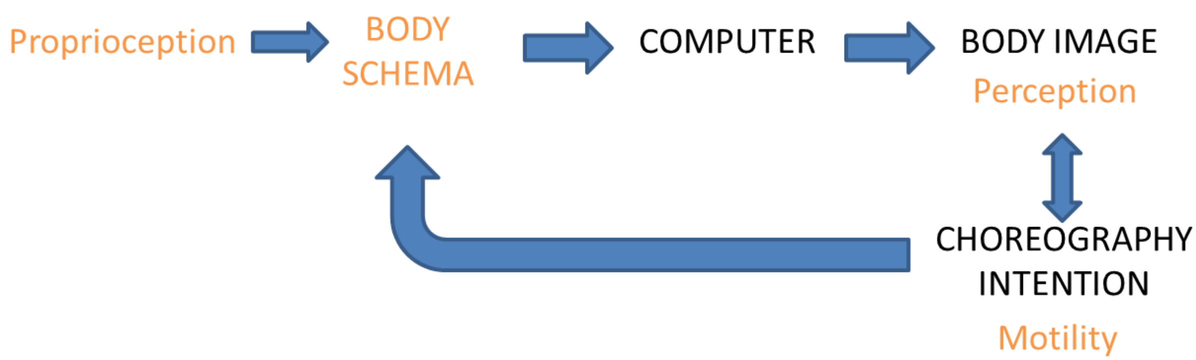


Fig.8 The networks of connections when a dancer is interacting with his body image.

Space Schema

So how does one go about designing a virtual space for real time interaction? Following up the mixed reality concept, the space is now much more than just a simple projection on a screen. It is another realm, with its own rules, full of opportunities which makes it equally, if not more, fascinating as real space. At the start of an interactive dance, a connection is established between the performer and the space, through the interfacing technology. We have the visualized space, the computer which is hosting the rules imposed by the designer and the performing body which becomes the mediator of the two. The dancer perceives the space shifting and along with the motility derived from the choreography/intention as well as the dancer's proprioception, the body schema becomes an embodied potential.

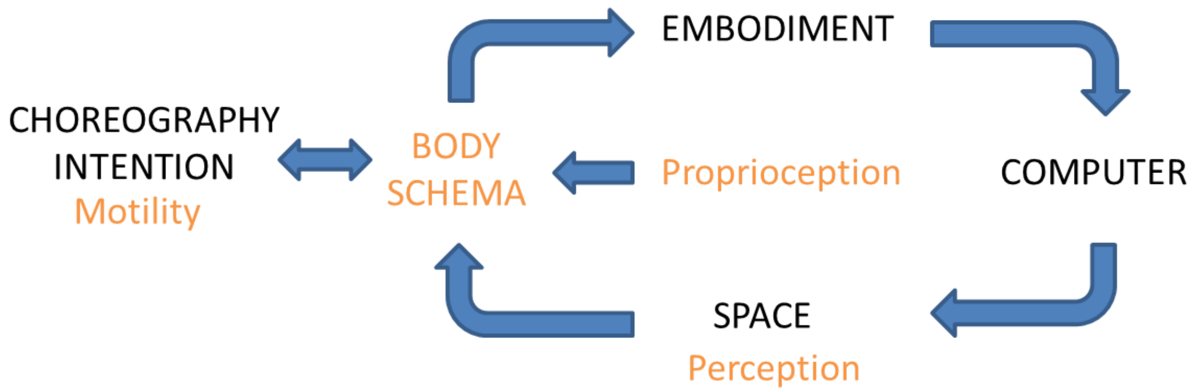


Fig.9 The networks of connections when a dancer is interacting with his body schema.

As we can see from Figure 9, the body schema is transferred through the embodied agent directly to the computer. As the body schema is digitized, the space architect needs to interpret the data in ways which make the space transform and not only become an extension of the dancer but also a dance partner with its own initiative which equals that of the dancer.

In order to create such a space, I propose that the underlying code of the program needs to simulate a system which shares the same characteristics as the body schema. Therefore the space needs to have its own motility, a sense of perception of the dancer and a sense of proprioception. These three process are then relayed into a forth process, which does the analysis and forms the projected space. I will call this fourth process the *space schema* (Fig.10).

Perception comes in the form of raw data from the performer, in the following way. The embodied performer, embedded with technology capable of digitizing his or her inputs, “a body-in-code”, extends his/her form with *interfacing technology* (e.g. wearable sensors or camera vision systems) and releases both consciously and unconsciously data signals which are being received by the system. These signals, which are then forwarded to the space schema, can tell the system a range of information such as the location of the performer in the physical space, movement patterns and movement intensity. Furthermore as the physical body and the physical space are now interconnected with the virtual realm, the performer can interact directly with objects from the virtual space.

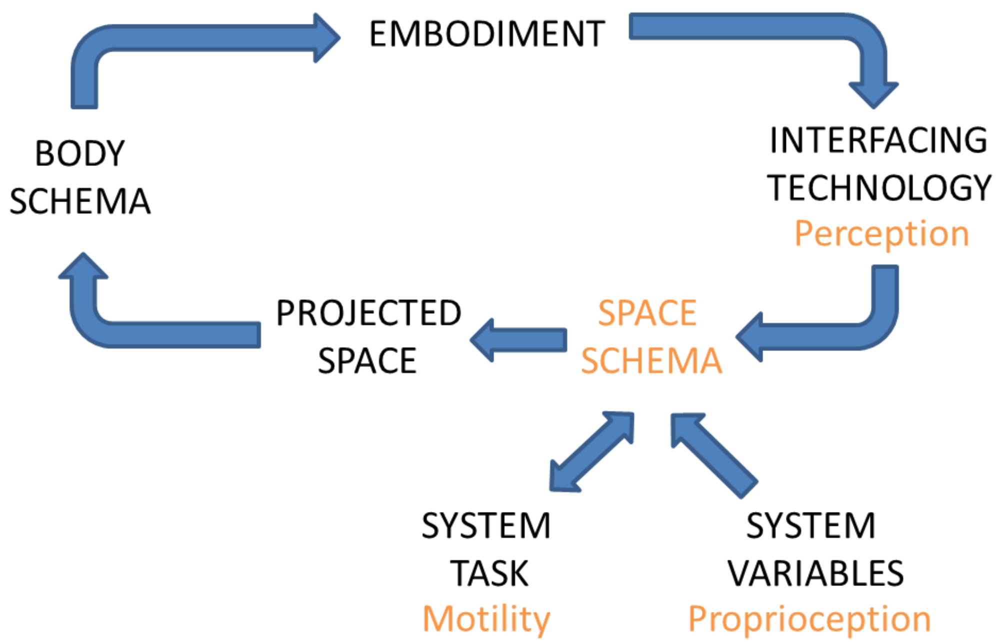


Fig.10 The Space Schema connections

By using a variety of sensorial instruments directly on the performer's body, acting as interface devices actuated by movement, movement quality/effort or touch, he or she can make a tree grow with a single raising of the hand. One action suddenly causes two different consequences in two different realms.

Proprioception is handled by a second process, which I have named *system variables*. All objects in a 3d space are distinct from each other and all of them exist in a Cartesian space. As the space exists in the digital realm, by default this makes it easy and simple to identify information such as position, orientation, movement direction and speed of each separate object. All this information can be stored in variables (variable in computer code terminology implies a stored number which is constantly changing to adapt) so the architect just needs to make sure that he or she assigns variable placeholders to all needed data. This data holds the current form of the virtual world, i.e. the state of all the objects in the virtual world. Variables dictate the possibilities and potentialities that can take place in the virtual space.

The final process handles motility, and I have named it *system task*. This process is responsible for instructing the system how to handle the external data. It is the internal "logic" of the system which guides the arrangement and use of the data in the space. As the *system tasks* processes the data, it lays out the existing evolutionary possibilities for the virtual world thus acting as a generator of potential movement. It is communicating directly in a two way communication with the *space schema* process, which as the main artificial intelligence of the space decides which of the evolutionary potentialities the world will follow.

Just like a performer in an interactive dance follows choreography, a set of rules which give structural "keyframes" to the dance, the *space schema* follows a set of tasks (provided by *system tasks*). These tasks are not pre-defined and neither do they follow a linear path; instead just like choreography they are a set of parametric rules which give the basic form of progression. In order to form the projected space, the space schema needs to combine data from all three processes. It receives (1) the movement of the performer in a digital form (2) the data of the virtual space in its current form and (3) the potential evolution possibilities. The space schema then applies a further artificial intelligence scheme, computes the result and renders the projected image.

In order for everything to work though, there is a special consideration which needs to be taken in mind. The system needs to work as a whole. If one of the three processes is missing then the results will not be reflecting the intended action. However, the three processes need to be able to work independently from each other as well. The system task cannot always wait for the interfacing technology to send it data in order to calculate the potential movement. The system task should be calculating the movement irrespective if it receives external data or not. Going back to the point I mention in the introduction, if the system is not a complete circle and it stops half way to wait for an analog input from the performer, then the system by default becomes incomplete. This system assumes an embodied presence with a non-interrupted data flow; however, if we want to create a realistic artificial dance partner, it should have the capacity to operate by itself in its own realm, without relying on what is happening in the physical realm. The performer is not meant to define the space, she is meant to shape it. For as long as the background processes are running the world should keep evolving, changing and adapting, and when the connection is re-established, the performer will not see the space as she left it but rather as the passage of electronic time has changed it.

Practice Work: *Suna No Onna*

Suna no Onna was conceived and directed by Johannes Birringer and Michèle Danjoux along with their team, the DAP Lab ensemble. It was first premiered in Laban Theatre Studio on Saturday 8 December 2007, followed by a second performance on March 14, 2008 in Watermans Art Center, London. During the summer of 2007 as a member of the DAP Lab I traveled along with the rest of the team to the Interaktionslabor, a laboratory for interactive media, design and performance on the site of the former coal mine Gottelborn, where the main production rehearsals took place. I was working along with Maria Wiener in conceptualizing, visualizing and creating the 3d animations which were meant to be projected as the main backdrops or scenographic environment for the performance. Our inspiration for the designs was mainly from nature and Michèle's costume designs which were developed together with the dancers and their particular characters. The 3d animations were subsequently rendered as a video file and carried to the Isadora programming environment for real time manipulation. In this section, firstly I will analyze the inspiration and the creation process of the 3d models and animations. Even though I was not an active member in the real time interaction of the videos, in the second part of this section I will still offer an evaluation of the methods of interaction, referring to theories from the previous chapter. Finally I will propose how things could have been done differently by using today's faster and more efficient instruments and software, as well as the platform I have developed during the last three years of my research.

Fig.11 A still from *Suna no Onna*, with Ren as the spirit woman with the blue overlooking the scientist (Taiwo) and the Woman (Isobe). Photo: © 2007 Dap Lab

Stage Design and Wearable Interfaces

"Suna no Onna is a slow moving sensual dance, a wordless drama merging virtual and real images of a life of existential entrapment in an apparently inhospitable and unstable habitat. The ominous sand dunes of Teshigahara's desert are transformed into a virtual projected environment that shapes the unconscious ground where the Woman (Isobe) meets a scientist-foreigner (Olu Taiwo) who stumbles into her life to become her captive" (Birringer/Danjoux 2009, p.107). Since the projected image would be a 3d animation, by talking with the stage designer (Hsueh-Pei Wang) we decided to create a set which showed firstly the uneven and semi-liquid surface of the sand as well as something which would enhance the sense of the third dimension. The end result created by Wang which can be seen in Fig. 12 below (suspended paper rolls forming a three dimensional curved space) looked beautiful with the projected image on top and served well to merge it with the sand on the ground.

Fig. 12 Stage design for *Suna no Onna* during the construction process, the suspended paper rolls applied by Hsueh-Pei Wang, on the left, and a still image from the performance at Laban Centre, on the right. Photo: © 2007 Dap Lab

Even though most of the characters were adapted from the narrative (in fact we adapted the film score of Hiroshi Teshigahara's 1964 cinematic interpretation of Kobo Abe's novel *Woman in the Dunes*), as the dancers started working on their movement, it became obvious that Birringer and Danjoux were guiding them using an interesting and unorthodox method. The conventional design processes begins with a 2d sketch and a static form, followed by a 3d realization of the garment. The directors wanted the performers to develop their movements in conjunction with the cloth, sensing and understanding the limitations and possibilities imposed on them by wearing it. "We explored movement, introducing partial garment structures and cloth to the initial frame: inviting the dancer to move with cloth, sensing and experiencing the qualities of the cloth (in front of our eyes/the camera eye), its potential and design possibilities. We analyze d the movements reactions initiated by the tactile stimulus of the cloth and considered how garment form and structure emerge temporally, i.e. through synergies of performance, sound, lighting and movement-image on the projection screen (Birringer/Danjoux, 2009). As the garments were integrated with sensors (in order to manipulate interactively audio and visual elements), every time the garment changed, the range of motion of the performers changed as well and along with it the data produced by the sensors. By following this technique, the interaction designer can analyze the stream of incoming data, thus developing along with the director, the performer and the costume designer an ideal situation offering a balance between choreography and technological embodiment.

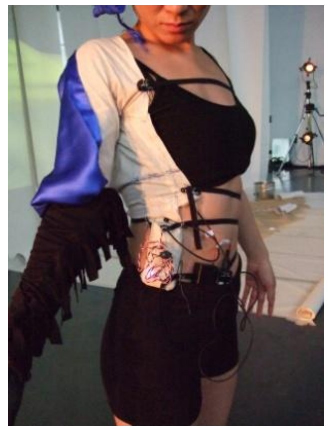


Fig. 13 Katsura Isobe performing (top right), Fig.14 Sensor configuration on Helenna Ren (top left) Fig. 15 Paul Verity Smith working on sensor interface (bottom right), Fig. 16 Garments by Michèle Danjoux (bottom left). Photo: © 2007 Dap Lab

Environment and Virtual Agents: Inspiration, Creation and Interaction

As this production was created in 2007, a few months after the beginning of my PhD research, I was just beginning to explore different methods of real time 3d interaction and of creating changeable projected scenographic environments. Most of the work at that point was done with Isadora or PD, both very capable platforms for performances. Unfortunately though, none offered the possibility of real time 3d rendering; therefore we were limited to creating pre-rendered animations and manipulating them through Isadora.

The whole performance was taking place inside an imaginary landscape of sand dunes, an inhospitable sandpit where the Woman was spending her time in isolation, living and working in her abode which she has to defend against the ever-moving sand that slides down into the pit. By following footage from the film as well as pictures from sandpits, a circular virtual environment was constructed made up of sand mountains and a small hut in one end. As the image was going to be projected from three different projectors, it needed to be split into three different images. This was tackled by placing three virtual cameras into the scene, positioning and orienting them to match our vision of the projected images and rendering them separately. The three rendered images where then taken to Isadora which handled the projection on the screens.

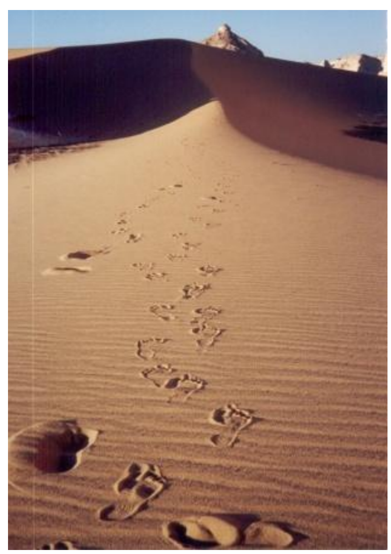


Fig. 17 Still from the film *Woman in the Dunes* (1964) by Hiroshi Teshigahara (left), Fig. 18 Research material for the dunes (right). Photo: © 2007 Dap Lab

Fig. 19 A still from the performance showing the Dunes. Photo: © 2007 Dap Lab

Along with the Dunes, two more characters needed to be developed. The first one was the virtual counterpart of the beetle woman, a playful creature which was meant to emerge from the sand and accompany the dancer (Helenna Ren) while she was personifying the insect world. By studying pictures of both the costume of the beetle woman and beetles, a 3d model was constructed and animated using humanoid motion capture data. The model was colored blue to match the costume as well as having eyes that emitted a yellow glow to symbolize the ethereal. The final result was a surreal insect which moved and jumped with ungraceful elegance, at moments standing up, and at others crawling around like a child but always complementing its dance partner while acting as a refreshing visual image on the moody sands.

Fig. 20 Garment concept design by Michèle Danjoux (right), Fig. 21 Ren interacting with the digital beetle (middle), Fig 22. Ren in the beetle suit (left). Photo: © 2007 Dap Lab.

The second character was a spirit woman, made entirely of sand. She was holding a glowing blue cloth emitting blue particles which slowly filled up the screens before falling on the ground and disappearing. Ren, wearing a different blue garment, danced and played with the spirit acting as a connection between the real and the virtual. As the virtual character was taking form from the sand it acted like the spirit of the space, waking up and showing its presence, reminding the audience of the power it holds over the Woman and the scientist. The model was done by taking a female humanoid model and applying a sand texture onto it. The model was then animated using motion capture data recorded in our studios by one of the dancers. A piece of cloth was attached to the model's hand and after a applying a cloth simulation in Maya it realistically followed the movement of the sand woman. Finally, the cloth was turned into a glowing particle emitter, releasing self-decaying particles at a steady rate.


Fig. 23 & Fig. 24 Ren in the Spirit Woman garment (designed by Danjoux) and the Spirit Woman animation on the background (left, right). Photo: © 2007 Dap Lab

Finally, a few more models and sequences were digitally created to accommodate certain narrative actions. As the scientist descended into the pit with a ladder, this was shown by a digital ladder appearing on the projected set environment. This ladder was subsequently "magically" removed, symbolizing the decision of the woman to keep the scientist there with her and entrap him. A sandstorm was also created digitally, creating a very powerful scene with the couple sitting down and the spirit woman holding an umbrella on top of them while the digital sand is trickling down. Finally, in the last scene, a swarm of beetles are seen bouncing towards the scientist, which were also digitally created using a particle replacement system.

Fig. 25 Olugbenga Taiwo just after he was lowered into the Dunes (left) Fig. 26 Ren holding the umbrella protecting the couple from the digital sand rain (right) Photo: © 2007 Dap Lab

Before moving into analyzing the interaction techniques, I will mention the hardware which was used for the performance. A number of sensors have been put into test (touch, bend, orient, heat, magnetic) but at the end it was decided to use only two. An accelerometer embedded onto sleeves and coat, and light sensors (photocells) embedded into the fish skin. The system used was an off-the-shelf I-CubeX from Infusion Systems and the transmission was done via Bluetooth. The data was transmitted wirelessly and encoded into MIDI for Isadora and PD to read. During the rehearsals it was noted that the I-Cube Editor software is less reliable when there are many simultaneous incoming data streams, thus the interactions were only used in particular scenes in order to allow the performers to familiarize themselves with the way the sensors operated (Birringer/Danjoux 2009). Oded Ben-Tal, the sound composer and engineer responsible for creating interactive sound in the performance, criticized the system as unreliable and very difficult to work with. In his paper “Musical Toys: Interactive Audio for Non-musicians,” Ben-Tal argues that “While it was possible to get a good range of reading from both sensors the whole system proved very difficult to work with: the wireless connection was not reliable; bringing all components of the system up (sensor, bluemidi, IcubeX, and PD) and talking with each other took a long time and often did not work at all” (Ben-Tal 2008, p.3).

The interaction between the performer and the virtual agents was done through Isadora, where the performer by using an accelerometer was given “editing power over her cinematic world … the sensortized garments moved the frames (forward, backward, fast forward, slow down, freeze-frame, jitter etc) within algorithmic parameters that also allow autonomy to machinic interpolations to generate motion ‘masks’ and corruptions that act as filters for the images” (Birringer/Danjoux 2009, p.118). As the dancer moved in the space, the accelerometer measured the rate of change of her movement sending a number (within a range of 1 to 127) to Isadora. The software, with the use of filters, changed the speed of the video playback (pre-rendered animation scenes) according to parametric values creating a relationship with the dancer on the stage. This effect created a dialogue between the real and the virtual, showing clearly a connection, chaotic at times, beautiful at others.

Evaluation

Working along with the costume designer and the stage designer was a crucial factor in creating 3d scenes which matched the vision of the performance. The beetle and the spirit woman were a perfect match to the eerie atmosphere of the performance, complementing the costumes on stage and adding a bit of a magical touch that enhanced the embodied sensorial interactive concept. The avatar's movement, created by humanoid motion capture data, worked well allowing the dancer to create choreography which showed signs of a dialogue. Even though the dancer's attention was split between her own proprioception/kinesthetic awareness of movement and the outer-directed "manipulation" or interaction with the projected 3d virtual environment, she was still moving in unison with the virtual constructs, feeling the projections "touching" the screen, and forming a partnership with them. Ren managed to successfully incorporate into her movement attention and self-awareness a giving and taking of the "weight" or the behavior of the avatars creating unique moments of contact improvisation. The dialogue, however, became predictable over time and at times it proved to be quite limited as the agent has no personality of its own and instead resembled a remote controlled virtual puppet that only moves forward, backwards or completely stops. Even though conventional 1:1 mapping was considered desirable by the team at that time (Birringer reasons "…that transparency allows for mimetic recognition of cause and effect which is pleasurable and (narratively) reassuring" (Birringer/Danjoux 2009, p. 109), the dancer however was forced to interact with an analogue agent in a digital form. As the path of the animated dance was pre-defined and linear there was no element of surprise or a differentiation of movement which would stimulate a response from the dancer. Furthermore, this has caused another problem related to the audience. Birringer addresses this in the essay on "Wearable Performance": "Since the exhibition of the work is presentational (in a theatre or gallery), audience observation and kinaesthetic empathy are inevitably drawn to the performer-image relationship, to the spatialization of the temporal media and the "logic" of connection" (Birringer/Danjoux 2009, p. 109). Since the relationship was meant to be a direct 1:1 mapping, the audience was constantly looking for one. In my opinion, the most successful interaction was when the dancer came quickly to a halt. That produced no data causing the figure to stop as well, thus showing the relationship in the most obvious way. By relating the technique used here to Hansen's body image and body schema, it is easy to see that the dancer was clearly responding to her body image. Motility was heavily dependent on the projected image, since the dancer was constantly trying to produce a response out of it. Unfortunately due to the nature of the analogue playback there could be no flow which resulted in the dancer creating brief isolated movements which needed to restart every time the virtual agent reached a standstill. As far as perception is concerned, in order to see the 1:1 interactions the dancer needed to mostly be facing the screen or try to guess how the agent would respond based on prior experimentation with the system.

The *Suna no Onna* performance was definitely a step stone for interactive dance performances. Most of the problems faced were due to technological limitations and knowledge, and now, after more experience has been gained and new possibilities of interaction tried out, could easily be resolved. Sensors technology has become much more reliable guaranteeing firstly that it will very rarely fail when used in a show and, secondly, that the technical set up can be much faster during rehearsal time thereby saving precious time. Technology is moving towards a mixed reality paradigm; therefore a number of questions which were raised during the performance are now becoming more relevant and are being investigated by a number of researchers. Birringer pondered about the possibility of having a whole body engagement with the virtual and acted upon it by integrating sensor technologies into the garments themselves. "It will become increasingly interesting to ponder 'narrative' or 'not-narrative' functions and cues of avatar choreographies in 3-D virtual environment, for which the player maintains a corporeal presence and 'plays' throughout the game with her body, involving cognitive and sensorimotor processes active in any engagement of spaces that can be seen, heard, felt, and intuited with the bodily intelligence. Instead of a wrist/hand interaction with the interface, whole body engagement opens up more provocative design challenges for the proprioceptive, cognitive, and physical processing of temporal and spatial experience – as it is fundamental for dance – in 3-D performance interfaces" (Birringer/Danjoux 2009, p. 110). The use of the whole body can be now fully realized with the introduction of new technologies. 3d technology has reached a point now where interactive real time 3d environments can be directly manipulated, i.e. the dancer can exist within the space and change the outcome of the projected image fluidly. This would eliminate the predictability and give the interactive animated world a flow which can work alongside the performer's continuous movement.

Reimagining of 3d-Environment

In this section I would like to propose a re-imagining of the performance using today's knowledge and technology. Instead of using pre-rendered videos, all visual elements would have been created and instantiated in a 3d game engine thus to allow real time 3d interaction. The idea would be to concentrate more on second generation interactivity instead of direct 1:1 mapping, proposing how both the sand dunes and the virtual agents can be created, exist in the space, interacted with and projected.

Starting with the sand dunes, the modeler would have to create an environment extending far beyond the visible mountains in the current version. The reason for this would be the potential of having not a fixed virtual camera but an animated one that could show the dunes from a number of different angles and cinematographic perspectives. Furthermore, a number of random occurrences out of the control of the performer will be taking place to make the dunes look more alive. These include random sandstorms, day and night cycles as well as insects appearing and disappearing in the background. The position of the sand Woman will be constantly observed and the dunes will slowly shift accordingly, building up a higher degree of sand volume to the opposing site. Furthermore, sand will also shift position when the sand Woman is performing her cleaning ritual.

The virtual agents will get a personality of their own. The beetle will be imagined as a playful creature which appears and disappears almost like playing a game of hide and seek. It will jump up in the sand and crawl around as well as sniff around and observe. The spirit woman would be a proud, higher power, which always exists there but is very rarely seen. A variety of hints might appear throughout the show but she would only fully reveal herself during the dance. Both agents can appear at random intervals for a few brief moments just to tease the audience. The head of the beetle can rise from the ground, watch for a few seconds and then disappear again. The face of the spirit woman can be formed discreetly on the sand or magical blue particles might fall along with a sandstorm. As soon as the agents appear for the dance, it is important that they have their own variable interchangeable choreography, just like the dancer. The virtual agents will dance and at the same time “observe” (through the sensors or camera vision) the actions of the dancer and respond to them, by combining these responses to their choreography. For example if the dancer dives to the ground the beetle can also jump and hide in the sand. Or if the dancer starts moving very quickly, the spirit woman will respond by creating a rain of glowing particles to create a powerful visual image. Technologically, this can be achieved with checkpoints. The choreography will be animated, split into a different number of moves and then chained together. An artificial intelligence system will be in place and if a movement from the dancer is identified, then the order of the clips will shift to accommodate the reaction. This process will create an uninterrupted flow which the audience will enjoy without constantly trying to identify what each moves triggers but rather watch a dialogue of two choreographies that complement each other.

Practice Work : *UKIYO (Moveable Worlds)*

The following section is about my second practical work, which consisted of a key interactive scene I was commissioned to build for the choreographic installation *UKIYO (Moveable Worlds)*, the expanded version of the original performance which was staged at the Artaud Performance Centre, Brunel University. The European premiere of the work took place in June 2010 at KIBLA Media Art Center, Maribor (Slovenia), and then it was performed again, with the Japanese dancers present, on November 26th, 2010 at Lilian Baylis Studio, Sadler's Wells, London. The performance has also been professionally recorded on a sound stage in order to create a cinematographic version. Therefore I will provide documentation from these three different sources.

Fig. 27 Katsura Isobe dancing the 3D creation scene in UKIYO, Sadler's Wells 2010 © DAP-Lab

A Floating World

UKIYO (Moveable Worlds) took place in a mixed reality space, immersing both audience and performers in a dream-like fragmented world which stimulated perceptions and emotions. It explored scenographic methods which connected the real and the virtual and the conscious with the unconscious by creating kinaesthetic relationships in a rich audio/visual narrative space. Birringer was inspired by the Japanese *hanamichi* (from the Kabuki theatre tradition) and Western fashion runways, and created a spatial design made of white cross-over runways populated by dancers wearing Danjoux's innovative garment designs which fused technology and fashion. The dancers would enter and leave their *hanamichi*, and sometimes there were solo scenes, as well as overlapping parallel scenes with two or three dancers, one of whom was also an instrumental musician. The garments, however, were constructed in such a way that the aural experience of the costumes was often as important as the visual. The amplified audio was a combination of acoustic and electronic processing, coming from a number of sources often unknown to the audience, and thus could be considered a form of acousmatic music. A number of digital videos and images were projected at times setting the mood and giving flow to the performance as well as enhancing the immersive qualities of the performance. My work, the “creation scene,” was performed towards the end of the performance, in Act II. It was an interactive scene, where a dancer (Katsura Isobe) existing in both the physical and virtual realms was performing a dance in midst of the audience. She was surrounded on all sides by performers and audience alike and part of her performance was to interactively create and shape a virtual island projected on a spherical weather balloon suspended from the ceiling, but at the same time attached to an air pump on the floor that was used by performers and audience alike.

Birringer, in his paper “Movable Worlds/Digital Scenegraphies,” makes a case for the importance of scenography and feels that sometimes it is considered as an underrated craft compared to the attention given to directors, choreographers, composers, playwrights and actors/dancers or musicians. “Yet scenographic practices – including set, costume, lighting, sound and visual projection/video designs – are fundamental for the construction of essential (dis)orientations without which in fact no performance would take place” (Birringer 2010, p.90). He furthermore argues, that since “our bodies were born to move, and we breathe and experience the world moving” (Birringer 2010, p.90) the use of “containers” for action, choreography, singing, music and the many forms of orchestration of sensory perception might need to be re-thought to accommodate contemporary practices. “Today, in a new century considered to be an advanced technological era of pervasive computing and networked connections, questions of space and movement hold crucial challenges for interaction designers and architects, and for those of us working in performance design with real time interfaces and immersive digital projections (video, sound, animation 3D graphics, virtual realities, network transmissions etc)” (Birringer 2010, p.92). In order to create this moveable world, Birringer continues, the work has evolved under three primary dimensions: 1) movement environment (spatial design); 2) movement images (projections of digital objects and virtual spaces); 3) movement of sound (from macro to micro levels), therefore giving to the production the conceptual metaphor “floating,” a concept which implies dissolving any borders between stage and auditorium (Birringer 2010, p.93).

Moveable, mixed, augmented and interchanged realities are the prevailing themes in all three of the *UKIYO (Moveable Worlds)* performances, exemplified best perhaps with the conceptual and dramaturgical shift occurring in Act II. The virtual stage becomes an alternative stage, where avatar-dancers in *Second Life* (created by our Japanese collaborators Kabayan and Gekitora) perform a “manga”-like choreography shadowed by the real performers in the real space creating a moveable reality which extends from the *hanamichi* space in the theatre/gallery, to the virtual 3d “floating world” which can be also visited by an online audience.

Furthermore *UKIYO (Moveable Worlds)* attempted to explore both the visual as well as the invisible and the acousmatic, with the Factory Woman (Anne Laure Misme) delving into aural immersion and dispersion processes. Danjoux provided the dancer with a garment capable of transmitting analog and silent audio, equipped with a functional microphone (and dysfunctional) speakers which paired with a vinyl record worked by the dancer, produced powerful noise music as in a factory; invoking an electro-acoustic virtual world which produces powerful sensorial immersion processes of aurality that Francis Dyson positions equally immersing (if not more) than the ocular-centric simulated environments of projected graphics (cf. Dyson 2009).

The digital phenomena take as much importance in space as the performers and they are considered as transformable living beings, a concept primarily exemplified by the creation scene that I worked on. Birringer, then, defines the work as “a continuous, evolving relation between the physical and the virtual in a space that never stands still and has no (single) dominant perspective” (Birringer 2010, p.96). With a variety of mixed media and mixed realities, the *UKIYO* space became itself an immersive environment. Live playing of the bandoneon (Caroline Wilkins’ instrument) was mixed with a pre-recorded sampled version of it, combined with the sound of the “breathing” when the instrument is expanded to take air in before pressing it out. In some scenes the sound of the dancing body was accompanying the rustling sound produced by the garments or the sounds of the garment-embedded speakers. The origin of the sound was not always obvious, making the audience wonder where it came from, a concept made even stronger by incorporating cracked media such as the dysfunctional speaker bra worn by one of the dancers (Anne Laure Misme). Digital images and videos were playing on the two opposite screens, forcing the audience to shift their perception from left to right as well as observe performers who were mixed with members of the audience to slowly begin their dance performances.

Each of the main dancers had their own hanamichi which would light up when it was time for them to perform and then slowly dim as the dance was coming to a close, only to be followed by the lighting of another hanamichi and another dance. Some of the performers often interacted with the audience by waiting for an input from them and offering them back a reaction. Others were imitating the virtual agents projected on the screen, creating a connection with the virtual in an unconventional, reverse manner. The creation scene on the other hand, accompanied the dancer in creating a landscape, an unfolding reflection of her inner self, interactively on the screen. The interactions were at some points obvious, at some others not so much. This constant uninterrupted flow of sensorial stimulations kept the audience captivated and created a feeling of anticipation of what will follow.

Matching the concept of the mixed realities, the creation scene exists and is taking place in two realms at the same time. The dancer is performing her choreography around a weather balloon, while an evolving world is being projected on to it. In the first showing of the performance, in Maribor, the projected image was displayed on a flat 2d screen. This proved to be not very effective, so a decision was made to change it for the next show. By using an inflatable weather balloon, suspended above human height in the air, the image is engulfing the sphere, adding extra texture and dimension to the image, while the dancer softly moves around it acknowledging its existence. As the dancer is wired with sensors, an interface controlling the virtual realm, the actions performed by her acquire a double meaning. Not only are they viewed by the audience as performing acts (the touch of a hanging leaf) but also they have an effect on the evolution of the virtual space. Starting from a flat concrete surface, the space is slowly transformed into a beautiful landscape, with mountains, grass, trees and lakes and populated by the eerie walking tree and mysterious black figures. In this section, I will analyze how this 3d virtual environment was created, what are its capabilities and interactions, and evaluate its effectiveness in the *UKIYO* performance as a whole. I will start by mentioning my inspirations and thoughts emerging from the different collaborations while creating the contents of the space, and then I will analyze how the space exists, interacts and evolves referring to my Space Schema theory from chapter 3. Finally I will try to analyze and criticize the relation of the creation scene to the performance concept, narrative and space. Most of the writing here will be theoretical, for more technical information please refer to the next section in chapter 4, "Theory of Code."

Inspirations and Concept Design

During the Tokyo *Ukiyo* workshop in December 2009, the first full team meeting since the first *Ukiyo* performance (presented in 2009 in the Artaud Performance Centre at Brunel University), Danjoux along with Isobe started to explore ideas for creating new characters. Inspired by the beautiful falling Gingko leaves flooding the busy university streets – the workshop was held at Hiyoshi Campus, Keio University – and looking for ideas to contradict the prominent industrial feel of the first show, they came up with Leaf Woman, a character engulfed in a dress of yellow leaves looking as if she spawned from nature itself.

Inspired by the landscape designs of Hiroshige and the evanescent, fleeting beauty portrayed in the Japanese *Ukiyo-e* artworks the team wanted to experiment with transmuting the inner dreams, beliefs and conflicts of the performers into surreal visual representations. The Leaf Woman, like a child of nature itself on an attempt to break the concrete cell of her industrial prison forms a safe heaven in her mind, the

Factory Woman (Anne Laure Misme) is virtualizing a cold abandoned factory, a steel fortress of reverberating sounds, and the trickster figure of the Kommissär (Olu Taiwo) builds up an army of shadowy figures to infiltrate the alternative universes of the other characters. Just like digital technology, the characters are broken down into code and reassembled in a virtual form, filtered through the colors, the textures and the visions portrayed in the art of Hiroshige and early 19th century *Ukiyo-e* artists.

Fig. 28 *Autumn Moon on Ishiyama Temple* from the work *The Eight Views of Omni*. Hiroshige, 1818.

We have a dancer appearing on stage looking for an escape from a corrupted industrial world, a place where she can find rest, peace and tranquility. Just like a shaman, she begins her dance, imagining the concrete world around her to crack, slowly revealing the nature she longed to see for so long. She does not want to immediately form an image of a nature scene in her head; she would rather take her time in doing it. Or even better create a playground for herself, one that she could use to repeat the process of creation. She wants this so much, that she does not want it to finish. This playground is her safety, as long as it exists; she can come back to it as many times as she wishes, eternally repeating the process. She knows that once the creation finishes, it is over. She would have to return back to her own world, the one that exists outside her own mind.

The place starts to emerge from her imagination. It is like an extension of her wishes flowing onto her dress, and then the dress extends all around her, creating a fortress of solitude. This world has nothing to do with the outside world. It has its own time, its own physical rules. In there she is the creator, she dictates what happens. She can invoke trees, she can make the grass grow, she can call for the sun or she can call for rain. Every single object in the world is connected with each other, it is aware of its own existence and of the existence of the others. It is constantly changing and constantly shifting. She has formed it, only she has the power to destroy it. The life span of the space depends entirely on her. The world itself is an embodiment of its creator. It has its own intelligence, because that is what the creator wanted out of it. In order to create a playground, the creator knew that the world must behave unpredictably. She would not want her creation to become repetitive. Therefore the space has developed intelligence, or rather has inherited enough intelligence from its creator, in order to perform the tasks at hand. There is a totality in her world.

The Leaf Woman though is just a person. Just like everyone, she is not perfect. Therefore neither can her creation be perfect. She has tried to replicate the work of nature, a task which is close to impossible. The knowledge she has passed to her world is merely how nature acts in her imagination. She has no idea how long it takes for a leaf to fall from a tree or how long it takes for a tree to grow from the ground. It takes as long as she wants it to take. And that is exactly what is reflected in her world.

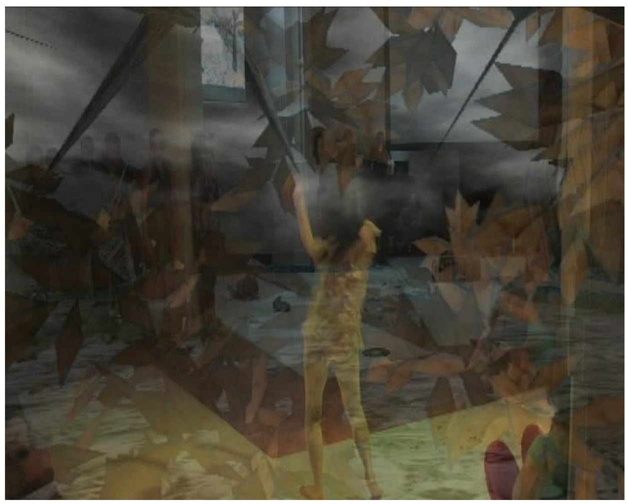


Fig. 29 Composite of real world and virtual world 2010 © DAP-Lab

The concept of “ukiyo,” in the Japanese traditional sense refers to an impermanent, evanescent world of fading natural landscapes, a realm divorced of responsibilities of the mundane everyday world. The world as viewed through the eyes of Hiroshige is dynamic, constantly changing, constantly evolving. As the virtual world is formed the creator of the space (the Leaf Woman) is faced with a concrete floor in the midst of an empty island, her feet touching the cold semi fragmented surface, the last connection to her real world. The space feels static, foggy, and the moody lighting makes most of the world undefined. She looks around the empty space, the dark and cloudy sky, and falls on the floor touching and feeling the familiar texture. She slowly realizes this is her world, the digital code is part of her and she has the ability to mould the space. She slowly gets up on her feet, gaining confidence, and with a jump cracks the cement. As she is struggling to understand how to handle this externalization of her embodied state, she realizes that the environment is no longer static. She notices a slight shift in the clouds, a slight movement of the wind. She jumps again, and this time her landing cracks the cement even more. She can feel the space moving and with a final jump the concrete is shuttered. The clouds are now moving, the wind is blazing, she has just kick started her world.

The Leaf Woman looks up in the sky extending her arms, willing the clouds to slowly subside. She can feel for the first time the sunlight on her skin. The colors of the world around her become brighter, she falls to the ground again, pushing the floor with strength from deep within her and as if by magic her code is erupting in the shape of mountains and rocks. The landscape takes shape just like a woodcut painting, carved by the momentum of the dancer moving in space. Lakes are formed, their crystal water reflecting the digital clouds soaring the sky.

The world, behaving like nature, is randomizing the Leaf Woman's creations. Rocks are generated in random locations, the landscape moulds following gravitational forces, water flows in random directions. The space has physical properties, the rocks will slide down mountains, the sky will pour down rain. Vegetation seems to develop by itself. The world is evolving, with or without the contribution of its creator.

As the Leaf Woman extends her arms once more to the sky she invokes her summoning powers. Grass is now appearing all over the island. At will, she can mash up the code from the ground which rises and recombines, forming trees which seem to tear up the ground and climb out, taking their stance magnificently on the surface while they heal the ground. Embodied with their own will power, like a code created from a code, these trees possess their own intelligence. They can walk around the space and possess spatial awareness. Leaves from the branches are gracefully falling to the ground, bending to the autumn desires of their creator.

Fig. 30 Katsura Isobe dancing during the creation scene in UKIYO, Sadler's Wells 2010 © DAP-Lab

The Leaf Woman is now playing with the space, her bare feet touching the grass while she moves elegantly around her trees. She invokes rain and magically makes the leaves from the ground follow her will and shoot high up in the air, directing them into shapes as they glide back down. As she changes the physical properties of the space, the rocks, the trees, the water flow upwards and as she switches the centripetal gravitational force to a centrifugal she watches the digital world decomposing into an outwards spiral, only to return back to normal state whenever she wills it.

The virtual environment, just like the Leaf Woman's imaginary world, has come into existence and lingers and floats in space. The synoptic flow, the theme and the mood of the "creation scene" had been placed into context by taking under consideration the architect's interpretation of the narrative, the artistic concepts of the *ukiyo-e's* evanescence worlds, the colors and compositions of Hiroshige's woodcuts, the vision of Danjoux's garment designs, Isobe's character development of the Leaf Woman and the fragmented immersive theme of the *UKIYO (Moveable Worlds)* production.

The garment wore by Isobe was uniting her physical presence with the virtual space, surrounding her and further extending on to the island, merging with virtual leaves and the trees, and become one with the code. Danjoux, reflecting on her work on the garment in an email communication after the workshop, described the leaves as "Their beauty in the real but transient world was quite spectacular as the sun shone through their fragile and ephemeral surfaces" (Danjoux 2010).[8] The garment was almost entirely made from leaves resembling a magical cape or cloak that covered Isobe body. Each leaf had to be "preserved carefully by hand to prevent further decay and disintegration. The embalmed leaves were then mounted and stitched onto fine silk tulle (base garment) with silken threads. Colors had become muted after time so some artificial yellow was sprayed onto some of the leaves to mimic the nature".[9] By investigating the garment's creation procedure, it is very interesting to see how it ties into the narrative design of the space. The Leaf Woman finds leaves scattered on the floor, fragments of a long lost world. Slowly she collects them, preserves them and embalms them, making a garment to act as an immersive tool into her metaphysical state. Commenting on the leaf's dress and the impact it had on her performance, Isobe said "This is my second skin. The boundary between my flesh and outside body, which is vague with this delicate fabric reflecting my body movement. The process of finding the material (leaves) for inspiration and, eventually, the garment is very important for my character building, as Michèle mentioned. The nature of leaves – fragility and ephemerality affected my narrative of the performance somehow".[10]

[8] Michèle Danjoux, email, 8th October 2010.
[9] Ibid.
[10] Katsura Isobe, email, 12th October 2010.

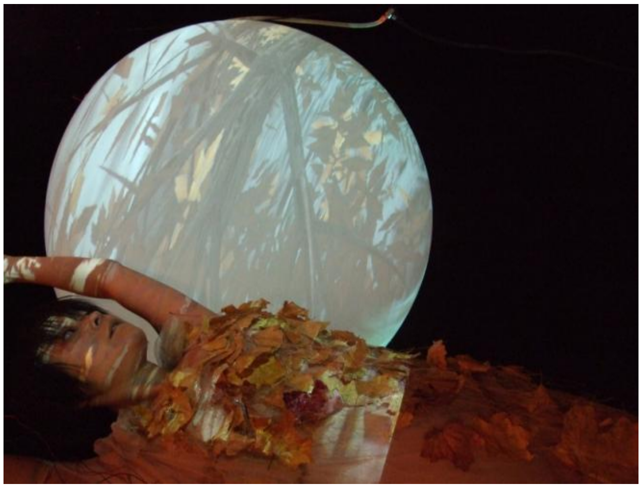


Fig. 31 Katsura Isobe, Sadler's Wells 2010 © DAP-Lab

Implementation

The “creation scene” in *UKIYO (Moveable Worlds)* was done in collaboration with a Katsura Isobe, a professional artist working with Birringer and his team since 2005. Even though Isobe is an artist deeply committed to physical, somatic and intuitive knowledge and expression, she has acquired fluency in working with sensor interfaces and real time performances. She is trained in Laban technique and also in Body Mind Centering and the Eastern approaches to concentration. Isobe is a person who practices a daily practice of embodied art/movement but is also willing to experiment with adopting “the virtual” into her movement, as a potentiality.

In the “creation scene” Isobe was in a mixed reality state, where she was performing in both the physical space as well as in the virtual environment. Through sensors, she was technologically embodied onto a VR system, which was designed to form and evolve a virtual world. The system was designed to accommodate a nature of collaboration with the dancer, where she was working along with an AI system to shape the evolution of the space. Even though the VE had the capacity to mutate without the need of an analog signal (such as input from the dancer) when the system was coupled with a dancer her actions took precedence over the AI. The Leaf Woman was leading the evolution, as this world was her creation, while the space offered elements of randomization and unpredictability.

Fig. 32 Composite of real world and virtual world 2010 © DAP-Lab

Five evolutionary stages, just like levels in modern computer games, are meant to steadily progress the evolution of the world from just a flat surface to a living and breathing island, with rich vegetation, mountains and trees. Unlike the world of *Osmose* where the immersant takes a spatial journey through the virtual planes of a real time world with a fixed progressive structure, the world in the "creation scene" unfolds depending on the action of the dancer. In *Osmose*, the variation of the experience between each user depended on the navigational path chosen by the immersant since the world they all experience was the same. In *Ukiyo* the land is an empty canvas forged and shaped by the dancer in real time, therefore every time that the scene is repeated, the final world is never the same.

As a method was required for switching from one evolutionary stage to the next, the "brush system" was devised, a simple method for the dancer to communicate with the system by using natural features interaction (for an in-depth explanation on how the "brush system" works, please see section *UKIYO Space Configuration*, in chapter 4, *Code Theory*). The "brush system" was inspired from modern natural gesture recognition systems such as the Kinect[11] and basic user interface tools such as toolbars from software packages like Photoshop. The dancer was able to make specific changes in the environment by choosing the appropriate brush. For example, by choosing the sky brush, she could change the color of the sky. The world creation is divided into five progressive stages (named: cement, sky, mountain, nature and final), and once the dancer moves forward a brush, she cannot return back to the previous one. This decision was made in order to give a forward pace to the whole dance section as there was a time

[11] Here is a video that shows the concept ideas of Kinect (previously known as project Nadal) http://www.youtube.com/watch?v=p2qlHoxPioM

constraint. Unlike traditional game stages moving from one brush to the next did not require the completion of certain conditions – with the exception of the cement brush which required the cement to break-. This gave flexibility to the dancer to make as many or as few changes to the environment as she required.

The progressive nature of the evolutionary system was aimed to create agency for the dancer, giving her goals which expanded both in the long run (form the island) and the short run (change the sky color, plant trees, etc.). The agency produced was aimed at increasing the immersive qualities of the space. The scene was incorporating both first generation and second generation interactivity, but unlike traditional first generation interactivity systems that produced dialogues by urging to performer to respond to audio/visual stimulations, in the "creation scene" the dance intention of the performer was meant to be stimulated by the sense of agency, the narrative and a sense of spatial belonging triggered by the reassurance of (technological) embodiment with the virtual space. In an attempt to explain further my argument, I will give a practical example. When the nature brush was activated the dancer gained the ability to plant trees. Even though this was achieved through a first generation interactive system (i.e it was triggered by the pressing of a sensor), when the dancer planted a tree, that did not guarantee that the action will be visible on the projected screens nor that the audience will witness it as that would depend on the position of the virtual camera in the space. The only person who knew for sure that a tree was generated was the performer who caused it, due to her technological embodiment. The shift from real time visual stimulations towards agency driven embodied actions was done in an attempt to offer the performer an immersive space that both stimulated more of her senses and at the same time produced an evolving visual spectacle for the audience.

The VE was visually represented by a moving virtual camera that projected the 3d space on a flat surface in the Maribor/Kibla Media Arts Center performance and on a spherical surface in the London/Sadler's Wells performance. The virtual camera was a first person camera view that took the role of a cinematographic camera mostly traversing the space in random patterns. As the scene faded in, the camera seemed to pan over an endless sea and finally arrived on a poorly defined island, zooming in on a concrete floor. As it entered the first brush, it remained still to show a close up view of the cement without revealing any other details about the place. As soon as the cement breaks, the camera turned to the sky signifying the second point of interest. The concept and theme of the scene still remained relatively undefined, and the first two brushes could be considered as introducing the audience to the scene by showing them the elements of interactivity and changeability. With the start of the 3d brush, the camera very rarely remained still, constantly moving towards a random point in space. The virtual camera was always facing towards the island but mostly not from an optimum position for the viewer to get a complete clear view of the whole space, a situation which can be considered ideal to fuel the imagination and curiosity of the audience. As the volcanic rocks erupted and the shaking landscapes grew to form the mountain, the camera zoomed across the floor flying through the shattered rocks displaying the evolutionary power of nature. As the vegetation grew on the island, the camera passed through patches of grass and through branches of trees creating interesting and surreal images. The lighting was mostly dimmed and an area of fog seems to be surrounding the island, creating an atmosphere of a mysterious, fading natural landscape encapsulating the concept of the Japanese ukiyo-e prints. As the scene approached a closure the camera concentrated more on the appearing stickmen, the foreign agents which invaded the space. The scene then turns into wireframe, exposing the code and causing it to fade back into blackness.

Evaluation

The *UKIYO (Moveable Worlds)* project was clearly a work which passed through evolutionary stages, improving with each performance. The creation scene was added in the second iteration of the production, and it introduced new ideas in the technical, the scenographic and the conceptual domains. I believe it was an effective addition to the whole production, merging well with the rest of the scenes. It left the audience with some visually strong images, stimulating their curiosity and making them wonder about the deeper connection that existed between the dancer and the virtual and the physical space.

Feedback from the audience, collected from discussions following the performances, attests to an overall enjoyment of the “creation scene” as it complemented perfectly the hybrid world, mixed reality, floating space themes of the production. Even though there were no obvious visual signs of interactivity after the second brush, the audience could detect a connection between the dancer and the virtual space which extended far beyond simple “triggering” of events. At times the space seemed to have a mind of its own appearing to lead the evolution, only to be submitted again to the will of the performer a few moments later. The arrangement of the physical space, the lighting, and the presence of the rest of the performers each immersed into their own multi-sensorial micro-worlds created a space existing in more than one medium. The dancer seemed to be inside the space, existing simultaneously in two realities, interacting purposefully with two interconnected ecosystems. The collaboration between the physicality of the movement, the plasticity of the digital world, the ethereality of the scenographic space and the theme of floating worlds seemed to have created a hybrid experience which could only exist and acquire symbolism and meaning when viewed as a fragment of the *UKIYO (Moveable Worlds)* production.

During the performance at the Lilian Baylis Studio (Sadler’s Wells), the virtual world was projected on to an inflatable weather balloon and the dancer performed around it, at times gently touching it and interacting with it. The projection was beautiful, the arc shape created the illusion of depth, making the 3d space look much more alive and vivid. The dancer was in a mixed reality environment and I would argue that second generation interactivity in a 3d space is actually a step closer to a fully immersive environment than first generation. Reacting to your body image produces greater agency but its immersive quality is short lived. It is a process of constantly reacting to what you see and as soon as this reaction is finished, in the in-between time just before the next cycle begins, immersion is replaced by a sense of completion. In the second generation interactivity though, the user is working towards a goal, a sense of direction that is always at the background urging her forward, which keeps the immersion there for longer. In the "creation scene," the sense of direction was always there.

Each brush system had a specific goal which was apparent to the dancer and created agency for her while trying to accomplish the goal on her own terms. Working along with sensorial stimulations, agency can act as a second driving force and immersion technique for the dancer, in the same way that it keeps a player interested and immersed in a game. The "moving forward" and progressive nature of the "creation scene" consisted of a number of short term goals all leading towards the completion of the main goal which was to create the island. This technique, being quite common in a number of computer and board games, is being used as a mechanism to keep the dancer's interest towards the virtual world always at its peak making it an integral element of the choreography.

During the first *UKIYO (Moveable Worlds)* performance in 2009, the online audience could visit a virtual replication of the space created in *Second Life* and explore the space from within. Video cameras were projecting in real time the physical performance in the virtual space, allowing the online users to watch the performance taking place in the Artaud Performance Centre at Brunel University through a "window" showing the real world. The construction of the *Second Life* virtual set offered an extra layer of observation perception to the production, allowing users to not only experience the performance without physically being at the Artaud Centre but also extended their presence in the ecosystem, making them a part of the performance for the people physically there who could see them navigate the virtual realm. Likewise for the online audience, the physical audience exploring the installation were also considered for them as part of the performance, essentially creating a blur between audiences and performers.

The *Second Life* virtual space can be considered an extension of the physical set, a virtual, floating placeholder of content and avatars, interconnected with the physical space. By controlling an avatar, the users enter the space just like the physical audience enter the Artaud Performance Centre. There they can explore their surroundings, observe system-controlled avatars performing their surreal choreographies and even interact with each other by utilizing the interface provided by *Second Life*. The system controlled avatars are placed in the space, given spatial awareness and perform their intention. There is, however, no interaction from either the visitors nor the system-controlled avatars that influence or change the actual space.

Michael takeo Magruder, an artist and researcher based in King's College Visualisation Lab and an advisor in the *UKIYO (Moveable Worlds)* project, in one of his case studies[12] with *Second Life* infused the space with an artificial intelligence system and cleverly personified part of this AI system by assigning it an avatar and a name. "The agent of this process is a third entity that resides within a hidden place. Resting atop a simple cube as if in contemplation, its body, stripped of all human essence and free from any influence, contains no consciousness. It is a doll within the world, an object within the metaverse serving as a collector of memories and recorder of histories" (Magruder, 2009 p.66). The "doll" as a "virtual shell devoid of all presence and integrated into the core fabric of the installation is observing the interactions happening in the space" (Magruder, 2009 p.61). Claiming the role of the facilitator of the space, the doll records those interactions and relays them forward for further processing. "Everything that ventures within the doll's dislocated view is captured and remembered. The images it records are transmitted out across the network to a server that algorithmically processes them into a serialized data stream. This material is then redistributed back into the network where it is accessed by the Second Life grid and reabsorbed into its source environment" (Magruder 2009, p.66).

In the "creation scene," as with Magruder's "Vitruvian World," there is one more force which interacts with the dynamics and changeability of the space, an artificial intelligence system embedded into the space fabric itself. In Magruder's work the doll has no will of its own, it just records the interactions and relays them forward. Using Magruder's analogy, in the "creation scene" the doll is no longer an "empty shell" but rather is assigned a number of decision making responsibilities. It observes the space, evaluates the actions and acting as a puppet master changes and evolves the virtual space.

This was the first attempt of this team to create an interactive 3d space for a dance performance, and it has left the team very satisfied with the result. Many of the audience comments received after the opening night attest to this. Some of the theoretical ideas however have proved difficult to implement, working out practically in a more simplified form. An example of this is the navigation of the virtual camera. Due to time constraints it was very difficult to come up with an algorithm to move the virtual camera in a desirable way around the space. The performer was not always looking at the projected space, therefore a

[12] "*The Vitruvian World: A Case Study in Creative Hybridisation of Virtual, Physical and Networked Space*"

decision was made that the camera was going to be manually controlled by the designer. This ended up producing an interesting relationship, since the dancer was interacting with an intelligent space as an external observer-collaborator was in real time choosing aspects of that relationship and showing them to the audience.

Scenographically, it might be interesting perhaps to experiment further by trying to replicate an immersive space on the set. This can be done with the addition of a transparent screen, where the image is projected on and the dancer performing behind it. The *UKIYO (Moveable Worlds)* project was a project encompassing a lot of the problems faced by new media art works, especially in the live performing arts. The introduction of interactive technology is definitely what drives the experience but at the same time what causes the limitations. In the next section, I will break down the technological requirements in constructing the “creation scene” and make an analysis of the code, demonstrating exactly the perspective of the artificial intelligence system of the virtual world. Further evaluation regarding the technological dimension of the various interactional relations in the performance will be offered at the end of the chapter.

Practise Work: Theory of Code

Artists and Software

Being part of a rapidly adapting community whose innovations are driven by experimentation and modification of new technologies, it is only natural to face problems derived from insufficiently sophisticated and quickly outdated software. There is a very limited array of software tools created and aimed for the digital artist, resulting in a plethora of artworks that look and feel as they were created from the same software package. At the same time, art projects are often making unconventional uses of new technologies, deviating from their intended use which can often results in unreliable and inconsistent functionality. In the recent years as technology is becoming more integrated into the cultural habits of everyday life, it is easier for practitioners in the performing arts to acquire a better technological expertise. Furthermore, with the rise of multi-disciplinary practices and ideas in contemporary pop culture a number of technologically skilled individuals take more artistic approaches with their work, resulting in the next generation of art creation tools. This new blend of interests has produced a new type of hybrid artists/engineers, thinning the line between the two disciplines. Along with this merger of disciplines, we are currently in the midst of the appearance of the new generation of software tools for the creation of digital artworks, with packages such as openFrameworks (created by Lieberman, Watson and Castro and a very active community) and Fields (created by Marc Downie) quickly becoming favorites by the younger and more technologically inclined artistic community. Older generation softwares like Max/msp, Processing and Isadora are still commonly used for performances and installations, chosen for their more simplistic and user friendly approach.

In an attempt to explain the main differences and similarities between the packages, I will start by breaking them down and exposing how they work. Openframeworks is defined by its creators as "a c++ library designed to assist the creative process by providing a simple and intuitive framework for experimentation. The library is designed to work as a general purpose glue, and wraps together several commonly used libraries under a tidy interface: openGL for graphics rtAudio for audio..." (Lieberman 2010). In order to display graphics on a screen (openGL is in fact one such library) a piece of code needs to be written which tells the computer to read the coordinates of points and matrices (along with some other data) and draw them on the screen. Once that piece of code is ready in order to become re-usable it is turned into a library. Therefore, every time something needs to be drawn on the screen, one can call on the library without having to rewrite the original code. OpenframeWorks, Max/MSP and all the other software packages are essentially frameworks which collect a number of these libraries, combine them together and make them available for the user.

The main difference between the packages is how they make those libraries available. Max/msp and Isadora have the simplest interface from all those packages. They work by simply choosing the library (conveniently and nicely packaged into a box, referred to in Max as an “object”, whereas the video objects in Isadora, for example, are called “actors”) and dragging it onto the graphical interface. The user will now see a patch with an object that is able to display any 3d model that is attached onto it. For someone who is after basic functionality Max/msp is ideal since it combines efficiency, speed and simplicity. The problems arise when a user wishes to use the library in a more advance manner, for example by gathering information which is not accessible through Max. As discussed before, a library renders a 3d model on the screen by reading the coordinates of the points from an external file. Accessing the position of those coordinates in a raw data form is not an option offered by Max, however a user might require them. Therefore the only way to access them is to “request” them from the library itself. This can only be done through coding. Openframeworks offers users a direct access to the library without the intermediation of another software tool. As C++ however is considered one of the most advanced and difficult programming language for someone to master, it is certainly a demotivating factor for a number of artists.

Marc Downie, in his interview with Birringer (Birringer 2008, pp. 261-83), mentions that all tools are exactly the same. What he means by that is that all the tools use more or less the same libraries, exposing to the user the same parameters therefore greatly limiting the variety of possibilities. For the *Ukiyo (Moveable Worlds)* project, which was discussed in the last section, I discovered that I needed much more functionality and variability offered by these tools; therefore I decided to take a different approach. As physics and collisions were a major part of the project the more optimized solution for the project was a game engine system.

Panda3d is a framework for 3d rendering and game development, commonly referred to as a ‘game engine’. The libraries it contains are commonly used for creating interactive 3d worlds, populated with modules that allow direct access to rendering, texturing, camera control, sounds, collisions between objects and basic artificial intelligence for gaming. The engine itself was written in C++ and is utilizing a wrapper that exposes the functionality of the engine in a Python interface. Essentially that means that Panda allows access to its libraries both by C++ programming as well as Python scripting. Just as Max/msp has a visual interface with connecting objects, Panda offers Python scripting which – even though it does not provide a direct access – is much easier to learn and implement. It is much more versatile than the interface provided by Max/msp, as well as offering the possibility of accessing the libraries directly by using C++ for anyone who wishes to implement additional functionality. The engine was developed by the Disney VR studio, a branch of Disney that was created to build 3d attractions for

Disney theme parts. Over time it has developed into a much more complete engine and was used by Disney for creating *Toontown Online* as well as *Pirates of the Caribbean Online*, two massively multiplayer online role playing games (MMORPG). In 2002 the engine was released as open source offered to universities so they could work with Virtual Reality technologies. Since then it is being supported by the Carnegie Mellon Entertainment Technology Center (Goslin 2004).

As Panda did not have in built libraries for camera vision recognition, a different external application needed to be used. After experimenting with a number of applications including Max/msp and EyesWeb, Processing (an open source programming language built for electronic arts and visual design communities, initiated by former MIT students Casey Reas and Benjamin Fry) was chosen because of its robust stability. I ended up using the JMyron computer vision library, developed and integrated in Python by John Nimoy, due to the library's reliable tracking (Fry 2001).

Finally, the last piece of software which I needed was Max/msp for connecting and sampling the sensor data. As the data was shared by the sound engineers and myself across three different platforms (PC, Mac and Linux) a decision was made to use Max/msp as it seemed the most mature system to handle the communication between these platforms. Max, a visual programming language for music and multimedia is developed and maintained by the San Francisco-based software company Cycling '74. It is one of the older platforms, developed as early as the mid 1980s for music production and passed through a number of iterations, including the addition of video and 3d in 2003, reaching its major update, Max5, in 2008 (Zicarelli 1997).

All of the above software and libraries, with the exception of Max/msp, are open source. Most of the software that are bought or downloaded only come in a compiled ready to run version. Compiled means that the actual code (called the source code) that the developer created was passed through a special program and was translated into a form that the computer can understand. Converting compiled code back into its original form is almost impossible; therefore companies use this as a way to prevent other companies from copying their code. Open source software works in the exact opposite way. The source code is given along with the compiled version encouraging communities and individuals to modify it with the aim of adding more functionality, fixing errors, adding a better interface and creating an overall better user experience.

For the rest of this section, I will analyze the technical requirements for creating the "creation scene". I will start by outlining the conceptual design behind the scene and then break it down and analyze each component separately, explaining how it works, what it offers to the system and how all components are put together and work with each other. My aim for this section is to provide an in-depth analysis of the processes undertaken by a designer to create a gesture based 3d interaction scene.

My purpose here is twofold, firstly so I can document and evaluate my work and methods and, secondly, to give 3d designers aspiring to work in the interactive medium as well as team members of other disciplines the opportunity to understand on a deeper level how the interaction works, what controls the evolution of the scene and what causes the birth and disappearance of the 3d content. As projects are becoming multi-disciplinary different team members bring expertise which can be hard to grasp by someone with no past experience of that area. As one of the many advantages of multi-disciplinary work is that fresh and new perspectives are offered by team members, it is important for everyone in the team to have a basic understanding of what constitutes creative coding and the scope of possibilities that might emerge from that. Furthermore, a basic understanding of the system would contribute towards a better performer - system interaction. As it has been identified in the first chapter, getting immersed in a 3d space requires a considerable time and effort from the performer. Both theory (experience based learning) and practice (game design questionnaires) showed that users tend to get immersed much faster and easier in an environment within which they feel comfortable and involved with. As experimental artistic projects are constantly evolving and ever changing, sometimes the performer doesn't have the opportunity and the time to achieve this familiarity.

As the navigation and interaction of each dance performance is project specific and depends on how the interaction designer calibrates and sets up the parameters there is usually no previous exposure to the system. As we are moving away from the direct action-reaction environments and are getting into more complex computational and parametric VE, in order to perform with virtual environments a dancer needs to be fully familiar with them. Here I am not suggesting that the dancer should know all the possible outcomes of all the possible actions; on the contrary, it is suggested that the performer gains a good understanding of the basic navigations, interactions and possibilities to the point it offers a comfortable familiarity. If these issues are not addressed, not only might it prevent immersion but also take away from the enjoyment of the dancer as well as providing an extra burden she needs to worry about. Finally, both Biswas and Trifinova pointed out in their respective papers that a major issue of the miscommunication between the disciplines is caused because of a failure to understand each other's requirements and specifications. I would argue that writing both general and project specific manuals can help minimize such confusion and promote a better collaboration.

Due to the nature of 3d interaction scenes, the code needs to be project specific. The theory however can be applied to a number of other projects as well as serve as a methodology for developing further implementations. Even though my code is written in the Python scripting language, I will not be showing any actual code in this section but rather use pseudocode as it is easier to understand as well as easier to translate to other programming languages. The aim here is not necessarily to explain how the code is recreated but rather to give an overview of the major processes, how they function and how they combine together.

UKIYO Space Configuration

During the “creation scene” in the choreographic installation *UKIYO – Movable Worlds*, the performer becomes immersed into her own virtual space, working along with the system, and aims to shape the Hiroshige inspired landscape, turning the dark industrial space into a peaceful green landscape with falling leaves or an icy eerie and mysterious forest with volcano rocks and walking trees. The main idea behind the interactions is the development of a language for the dance to communicate with the system. A decision was made to create evolutionary stages, which would change the space slowly allowing the dancer to have an active input in them. One of the first questions that needed addressing was the time frame of each stage. One option would be that the artificial intelligence of the space makes the decision but after discussing this with the dancer we decided against it. As the choreography of the dancer had not yet been developed, it was better to leave the change up to her. In order for this to be achieved I have divided the environmental evolution into five different stages and invented the brush system which the performer could use to switch between them.

The brush system is a simple method developed to allow the dancer to talk with the system by using natural features and movement/poses in the physical space. It is designed to be similar to a painter facing an empty canvas. Depending on what he/she wants to paint the painter picks up a different brush. The same applies for the performer. The main challenge for the interaction was to find a balance between movement and environment manipulation. As I understood from the feedback I received from the dancers that they prefer to know what each movement will generate. I therefore needed to think of a suitable way to allow enough freedom to the dancers to perform their intention as well as make transparent to them what they are currently generating. So, going back to basic user interaction methods, I have thought of a simple brush system that allows for a natural progression from one evolutionary stage to the next. It offers both functionality and flexibility to the dancer by integrating the postures into her choreography.

In the particular scene that is created we need five different brushes. As the scene starts, the dancer needs to crack and break the cement landscape I had built. This symbolizes the powerful impact of natural forces over the industrial. By going down to her feet, she accesses the first stage. As soon as the "cement brush" is activated, she can with a swift jump make the cement crack. When she repeats this three times, the cement completely breaks and then disappears. As soon as the empty ground appears she can now look up in the sky, raise her hands and the system will put her into the second mode, the "sky brush". She can now use the pressure sensor she wears to change the color of the sky. This not only has an immediate change on the projected space but also consequences to the evolution of the stage. The dancer here can choose to leave a dark moody sky or shift it towards a bluer, brighter sky. If the sky is turned bright then the mountains and trees which will rise in the following brushes will be different than if the sky is dark. Bright sky signifies a blossoming summer theme whereas the dark sky signifies a winter mood.

When the sky has been decided on, the dancer can crouch down, touch the ground and the system will put her into the next mode, "the mountain brush". In this mode the dancer can cause an eruption, lift stones from the ground and create a mountain. The size of the mountain is controlled by the dancer by selecting the height she wishes. Her action also populates the scene with volcanic rocks and gives the space a general shape by moulding the ground as well creating small lakes. The next mode, which is called the "grass brush", is achieved by raising the hands to the sky again. As soon as this mode starts, grass will start growing from the ground. The dancer will now be able to call trees, which tear through the ground and rise to full height. The trees are randomly distributed over the area of the landscape and, again, the number of trees depends on the dancer. Finally, when the island is fully covered with virtual agents, in the last mode the dancer breathes life into the space. By extending her arms the system moves into the "nature brush". The tree branches now move with the wind, leaves fall down from the trees, a surreal walking tree resurrects from the ground and the water in the rivers start to flow. The dancer can now invoke rain and play with the falling leaves by using her two pressure sensors. The virtual camera will move around the space in a cinematographic way, passing through the trees and grass, showing all stages of evolution. Its movement will not be pre-defined but randomized. Virtual stick men might suddenly appear towards the end of the scene, showing the intrusion caused by external agents just before the scene deconstructs into a wireframe mode and slowly fades away.

Interactive Technology

In order for the scene to be interactive, data must be received from an external source. In our case we are using a performer. Collecting raw data from the performer can be done by a number of input devices. In the *UKIYO (Moveable Worlds)* project a camera vision system and two touch sensors were used. On the software side the brush system was devised in order to facilitate the main interactions after the data is received.

The communication between the performer and the computer is achieved by programming the system to track and identify certain body postures. When the dancer wants to move to a different brush, she strikes a pose, the system recognizes the pose and checks the particular brush stage the dancer is currently in. The information is then passed into an algorithm which compares the current stage with the intention provided by the system identifying and offering possible subsequent stages. The computer then processes the information and makes the appropriate shift. As the system is constantly tracking the performer, one possible issue that might confuse the system is the dancer striking a changing pose by accident. This can be avoided in a number of ways. One possible solution would be to have a designated space on the stage which the dancer only approaches when she wishes to make a brush change. A second way, provided the dancer is also wired up with sensors, is to activate one sensor first informing the system to wait for a pose input and then strike the pose. A third possible method is to strike the pose for a specific time frame (for example 3-4 seconds) in order for the system to make the change. To minimize the possibility of an error, more than one of these methods can be combined. In *UKIYO (Moveable Worlds)* a combination of method 2 and 3 were used since our dancer was wired with two sensors and her choreography was paced in a manner which allowed her to stay still for a few seconds.

JMyron, the computer vision library I used, works with blob detection. The two most common ways to identify a moving object is by either comparing the color of the object against the color of the background or by comparing the change of color composition against sequential frames.

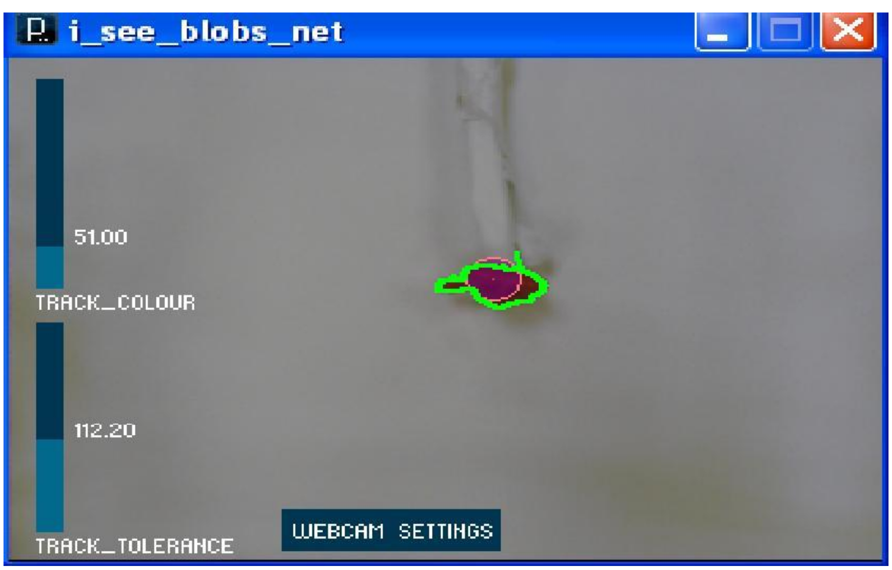
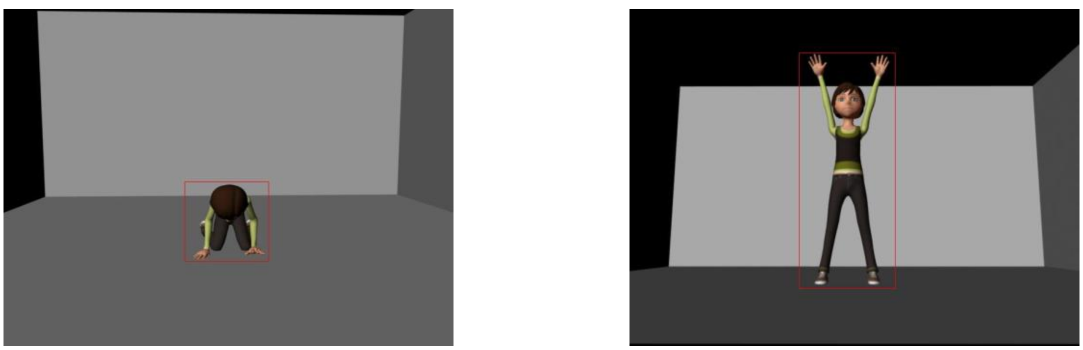


Fig. 33 Initial detection tests.

As the object is tracked, boundaries are drawn around it and the center of the object (referred to as the center of mass) is calculated and then printed out as a coordinate (x, y). The resolution used in this case is

320 x 240, which is perfectly satisfactory for tracking a dancer on the stage. Therefore when a performer is standing on the top left part of the tracking space the printed coordinate will be (0, 0). As she starts moving towards the right, the x coordinate will increase and as she moves towards the bottom the y coordinate will increase, both peaking at (320, 240) when the performer reaches the bottom right corner of the tracking space. The (0, 0) coordinate was chosen to be the top left as it was the default from the library but other than that it has no further importance.

Apart from the center of mass, JMyron is used to gather a second set of data. The center of mass is used to track the location of the performer, but that data alone cannot identify any poses. As the movements of the extremities of the performer are also required a method called the bounding box is applied. The performer is surrounded by a self-adjusting box that follows the body composition and can be used as a reference method to identify poses.



Figs. 34 & 35 Bounding box – Kneel down/Raise Hands.

By using a processing script, the collected data is then forwarded into the game engine where they are placed in variables for further processing. The following data are sent:

- X coordinate of the center of mass.
- Y coordinate of the center of mass.
- X coordinate of the bottom right corner of the bounding box.
- Y coordinate of the bottom right corner of the bounding box.
- Width of the bounding box.
- Height of the bounding box.

In order to minimize lag, it is optimum to send all 6 values in one single message. This is done by adding all values, separated by a “space” in a single string. So for example the message which will be sent will look something similar to this: “20 40 15 3 150 215”, where the numbers correspond to “X center of mass, Y center of mass, X bounding box, Y bounding box, width, height”.

As soon as Panda receives the data, it is instructed to take the line of string and identify the corresponding numbers. Due to a small issue with the network protocols, the two programs can only exchange data in the form of strings. As Panda then requires the data to be in the form of an integer, it needs some further processing in order to convert them. The 6 values are then placed into variables which are constantly updated through the interfacing technology process.

Data can be transferred from one application to the other though network protocols. The two most common protocols are a UDP and TCP protocol. The main difference between the two is that TCP after sending data waits for confirmation that the data has actually been received. Even though this is a more effective way to avoid errors, it makes the whole system slower. In our example we are using a UDP protocol, because we want the data to be transferred as quickly as possible.

The computers need to be connected on the same network and properly set up. A unique address (called the IP address) needs to be assigned to each computer when it is originally connected onto the network. Furthermore, a port number needs to be selected. Data leaves from a machine through a port and arrives at the other machine through another port. In the case of both programs running on the same PC, then the IP is the same. Therefore instead of a number the term “localhost” needs to be inserted instead.

The data from the sensors are sent through the same protocols and using the same procedure. When Max receives the data from the sensor, it is in the form of a number. This number ranges from 0 to 255, with zero pressure sending a 0 and maximum pressure a 255. Since there are two sensors connected onto the system, they need to be merged into one integer and then sent. This is required to minimize the total number of items sent and also to avoid opening two receiving ports in Panda since both of these actions will increase lag time. The values are then inserted into variables which are made publicly available by the system.

Space Schema

Following my definition of s*pace schema*, discussed in chapter 3, I will now show how this theory can be applied when one is creating a virtual space. The s*pace schema* in order to create the projected image, is assisted by three processes. The *Interfacing technology* collects the raw data from the performer, the *System Variables* which handles the storing and updating of the data and the *System Tasks* which informs the system how to handle the data and create evolutionary movement potentialities. The data derived for the results of the three processes are then relayed to the *space schema* which as the main artificial intelligence of the space, processes the data and creates the projected world.

In *UKIYO (Moveable Worlds)* the collection of data in the *interfacing technology* process is achieved by wiring the dancer with sensorial input devices. She becomes embodied into the space, mediated by the technology that digitizes her movement effort and touch into data. The system is now able to perceive the performer, see her position in the physical space and observe its conscious and unconscious movement patterns. The dancer was wired with two pressure sensors, both available for her to touch at any given time. The first one was on her palm, and the other one was attached onto a leaf which was hanging from her sleeve. Furthermore, the dancer was constantly followed by a camera vision system which could identify her position on the stage (in a 2 dimensional manner, left and right) as well as some basic postures (kneeling down, raising arms, extending). The raw data are understood by the system and rationalised into commands (for example: dancer is on the left side of the stage and kneeling down). These commands are subsequently used to change "brush" as well as sent a signal that the pressure sensors have been pressed. Therefore, every time there was a change of brush a message was relayed to the main system and every time any of the pressure sensors were pressed, the message was likewise relayed to the main system along with the pressure intensity.

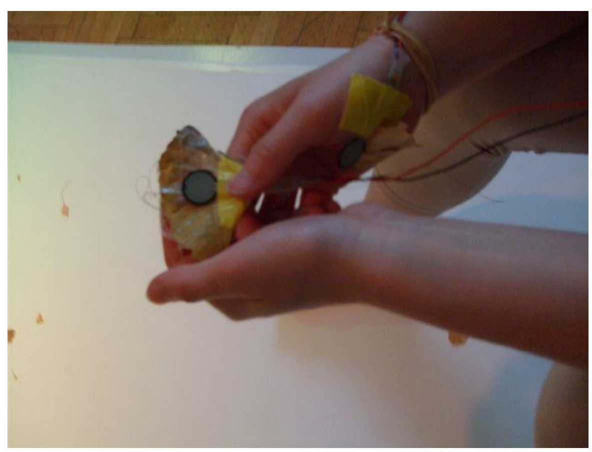


Fig. 36 Isobe wired up with sensors (left) Fig. 37 Leaf sensor (right).

The *System Variable* process assumes the role of the proprioception of space. Its responsibility is to understand where each virtual agent is at any given time. The 3d scene, during the duration that it is running, it populated with a number of virtual agents in the 3d space. As these agents move constantly based on random parameters, a process needs to be in place which can track their movements. In the "creation scene", we had variables set up for identifying the colour of the sky, the height of the mountain, the position of the trees and grass and the position of the walking tree and avatars. The data was then subsequently relayed forward to the *space schema* as well as to the *system tasks*. Furthermore this process makes sure that that coordinates of each fixed object (such as trees, grass and rocks) are marked, so that no other object will grow onto the exact same spot.

The third process, called *System Tasks*, assumes the role of motility. It is responsible for supplying the main system with information about possible forms of movement, or more appropriately, in the "creation scene", about possible forms of evolution, since we are dealing with a landscape. Even though the data coming from the *System Variables* was plentiful and of great variety, due to simplicity and time constrains we have only based the choice of evolution on just one consideration, the colour of the sky. This process receives the sky colour (in the form of a number from 0 – 100) and lays out the potential evolutions (green or white mountains) to the main system.

The *Space Schema* receives data from all three processes, and by employing an artificial intelligence system it processes the data. The *Interfacing Technology* sends the type of brush the dancer is currently in, which sets the mode the main system is working in. There, according to the current mode, the system isolates the required data from the *System Variables*, combines that with the data from *System Tasks* and produces the projected space.

I shall now break down the seven most importance processes of the "creation scene" and analyze how each one runs. The code will be broken down to four parts: (1) The System Task where I shall explain the purpose and intention of each process; (2) The System Variables where I shall show all the required data that the process needs to run, mentioning what each one is and where it originates from; (3) The Interfacing Technology where I shall explain the external data inputs; and (4) The System Task code where I shall post a pseudo-code of how the process is assembled and run.

Process 1 : Data Interface from the sensors:

System Task:

This process is running on the background and is constantly looping. Its purpose is to check if there is any pressure detected in the two sensors, and to assign the values into their corresponding variables.

System Variables:

UDPData // The data coming from the UDP network protocol.
PressureSensor1 // The value of the first pressure sensor.
PressureSensor2 // The value of the second pressure sensor.

Interfacing Technology:

PressureSensor1 = Analysis of the sensors library to calculate applied pressure on sensor 1// Performed every frame.
PressureSensor2 = Analysis of the sensors library to calculate applied pressure on sensor 2// Performed every frame.

System Task Code:

```
If program is running:
        If UDP receive = true //If data is coming from the network.
                If data.first //If the data is from the first pressure Sensor.
                        PressureSensor1 = data.first //Assign it to 1st pressure sensor variable.
                If data.second //If the data is from the second pressure Sensor.
                        PressureSensor2 = data.second // Assign it to 2nd pressure sensor variable.
```

Explanation:

This process aims to collect the data from the two pressure sensors. It is always running in the background and the code line If UDP receive = true keeps checking if there is a data stream coming in. As soon as data is detected, then by passing it through a filter, the system detects if the data is from the first sensor or the second and assigns it to the appropriate variable.

Process 2 : Selecting Brush

The performer can enter the selecting brush mode by firstly pressing the first sensor and then taking one of the following poses:

Figs 38 & 39 Poses for detecting brush. Kneel down lower bounding bos (left) Hands up, bigger bounding box (right).

System Task:

This process runs on the background in order to check if the performer is trying to change brush. It is activated as soon as the second pressure sensor exceeds the mid value threshold (115). When it is active it checks if the performer is in a pose that would initiate a brush change. The process is set up to record at the brush the performer is currently in and if there is an attempt to change brush; it makes the shift according to the following order: cement, sky, mountain, grass and nature. Cement and mountain need a crouching activation pose, the sky and nature need a hand rising and the nature brush need a wide arm extension.

System Variables:

CurrentBrush // Identifies in which brush the system is in.

PressureSensor2 //Value of the pressure sensor.

BoundingBoxLocation // The location of the bounding box in the space.

BoundingBoxCorrectLocation //The location where the bounding box needs to be if the brush will be changed.

Interfacing Technology:

PressureSensor2 = Analysis of the sensors library to calculate applied pressure on sensor 2// Performed every frame.

System Task Code:

```
1 If PressureSensor2 > 115:
2         If CurrentBrush.End = True // Checking if the current scene is finished.
3                 BoundingBoxCorrectLocation.Get // Assigning wanted bounding box location.
4                 If BoundingBoxCorrectLocation = BoundingBoxLocation //Check if they are equal.
5                         CurrentBrush = CurrentBrush + 1 //Moves to the next scene.
```

Explanation:

In the "Selecting Brush" mode, the system is concerned with selecting and changing brushes. There are four variables which contained data for this process. The CurrentBrush is a variable that contains a value representing the brush mode the system is currently in. The PressureSensor2 contains the current value of the second pressure sensor (the one attached to the leaf). The other two variables are placeholders for the coordinates of the bounding box.

In line 1, we check if the pressure sensor is touched. As pressure is applied to the sensor, the value is increasing in a range from 0 to 255. We assign here a threshold value of 115, implying that if the pressure is greater than this number the dancer is trying to change brush and the system should advance to the next stage of the code. If the pressure is lower than 115, nothing happens.

The next line in the code (line 2) is checking if the CurrentBrush has been flagged as complete. This is a precautionary measure to make sure that the dancer will not accidentally switch brushes half way (for example before the cement is completely broken in the first brush). If the scene is complete, then the code can move to the next line.

The next step (line 3 and 4) is to identify the possible bounding boxes combinations in order to advance to the next brush. For example, if the cement brush just finished that means the sky brush needs to follow. In order for the sky brush to be initiated, the dancer raise her hands. That means the values of the bounding box need to reflect the raise hands posture. BoundingBoxCurrentLocation.Get gets the value of the sky's bounding box, BoundingBoxLocation gets the value of the bounding box the dancer is currently in, and the code line : If BoundingBoxCorrectLocation = BoundingBoxLocation checks if they are equal. If there is match, the CurrentBrush variable gets a +1 value, which means there a brush progression (e.g. from cement to sky).

Process 3: Brush 1-- Cement:

In the first stage of the "creation scene" in *UKIYO* the performer is faced with a concrete cement floor which she needs to break.

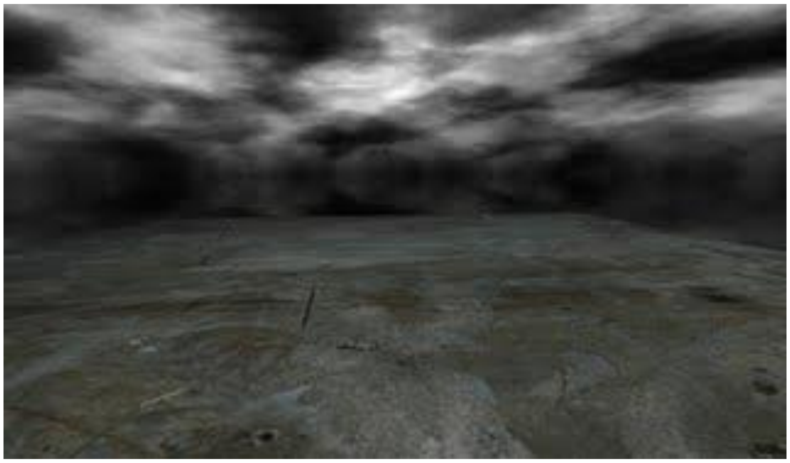


Fig. 40 Concrete Floor.

The dancer then needs to enter the cement brush by going into this pose for 3 seconds:

Fig. 41 Performer on the group, striking a pose for 3 seconds.

After the cement brush is activated the performer can perform a jump in the physical space. Using the data from the blob detection, the system constantly checks if the center of mass is above a certain threshold.

Figs. 42 & 43 & 44 Dancer performing a jump, midsection moving beyond the threshold.

If the dancer jumps above a certain threshold, as soon as the performer lands the cement is cracked.

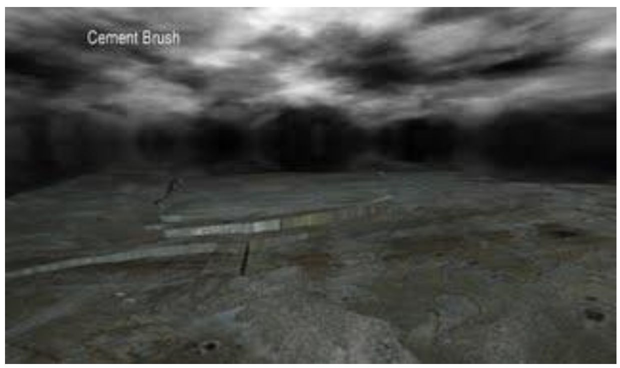


Fig. 45 Cement Cracks.

When the move is repeated again, the cement cracks even more, and in the third time the cement explodes away, revealing a green landscape underneath.

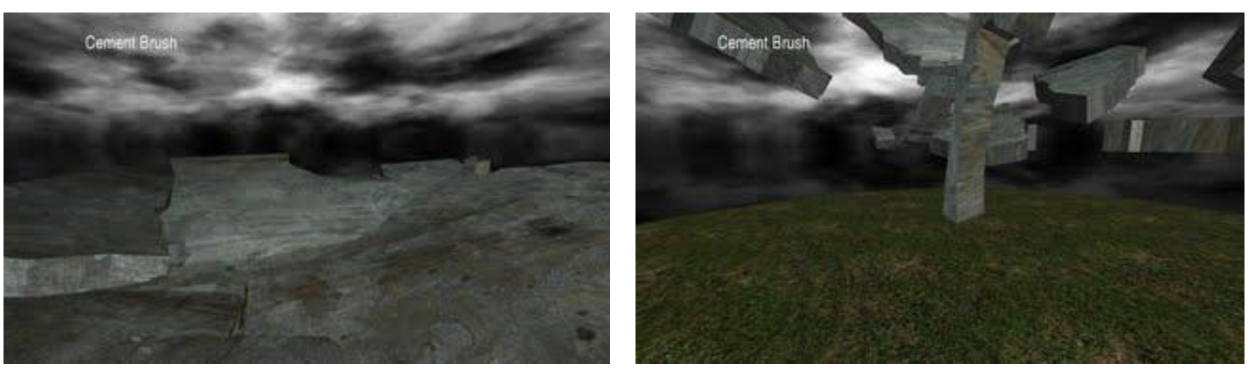


Fig. 46 & 47 Cement further crack, cement shutters.

System Task:

When the performer is in the cement brush, she can interact with the cement floor. By jumping more than a certain threshold she can land and crack the cement. When the cement is cracked three times, it breaks and disappears completing the brush.

System Variables:

CalibratedMidSection = Value from Calibration //This is the value of the midsection at the standing position. It is being calculated as soon as the performer walks in the scene. This is taken from Interfacing technology.
dancerMidSection = Center of Mass // This is the center of mass from the blob detection. It is changing every frame. This is taken from Interfacing technology.
JumpCoefficient = 125% // The percentage of increase in height required in order for the jump to register as true. This was set by the designer after trial and error.
Counter = 0 //Counter that measures how many times the cement was cracked.

Interfacing Technology:

CenterOfMass = Analysis of the vision library to calculate performer's center // Performed every frame.

System Task Code:

```
If ((dancerMidSection − CalibratedMidSection) / CalibratedMidSection ) * 100 > JumpCoefficient //formula.
        Play Break Cement animation //playing the cement animation.
        Counter = Counter + 1 //Add 1 to the counter.
If Counter = 3 // Check if counter has reached 3.
        Disappear Cement //Make the cement disappear.
```

Explanation:

Brush one uses four variables. The CalibrateMidSection variable is the value of the midsection of the dancer. As the system will be checking if the dancer performs a jump, it needs to have a base value to compare it to. This value is either assigned by the designer, or captured by the system at the beginning of the scene and remains constant throughout. The second variable, dancerMidSection, is the real time value of the midsection of the dancer. As the dancer moves around the space this value changes along to reflect the change. The third variable is the JumpCoefficient and this one is assigned by the designer at the beginning of the scene. It is the minimum increase in height that the midsection must travel in order for the system to register a jump. The counter variable simply counts the number of times the dancer has performed a successful jump.

The first line of the code applies a mathematical formula that checks if the midsection has travel a greater upwards distance than the threshold set in JumpCoefficient. If the result is positive, then the cement crack animation is played and the counter increases by 1. When the counter reaches 3 (line 4), the cement completely disappears.

The reason the space schema is applying a simple mathematical formula, is because the system was built with flexibility and adjustability in mind. Instead of a percentage coefficient, it would have been much simpler to just insert a static threshold (for example, if the center of mass moves above 1.2 meters) – a number which could be found with some experimentation with the performer. This would mean, however, that the system would need to be manually changed every time a new performer moves into the space, as the two performers might have a different height.

Process 4: Brush 2 -- Sky:

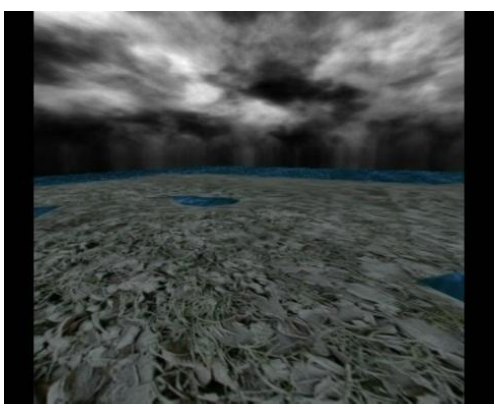


Fig. 48 Dark Sky, Fig. 49 Camera rotating to display sky.

System Task:

As soon as this brush begins, the camera turns and faces the sky. After the camera pan, the performer by applying pressure on the sensorthe performer can shift the sky color from the default dark moody grey to a peaceful light blue. Depending on the color of the sky at the end of this brush, the textures and the tree models of subsequent brushes change accordingly. If the colour is past the midpoint value (dark blue) then subsequent content will have the summer theme. If the content is below the limit, the content will have the winter theme.

System Variables:

PressureSensor1 // The value of the first pressure sensor.
Sky_color = 0 // The starting color of the sky is completely dark.
Sky_threshold = 127 // Threshold to switch between moods.
Scene_mood // This will be assigned to either Summer or Winter.

Interfacing Technology:

PressureSensor1 = Analysis of the sensors library to calculate applied pressure on sensor 1// Performed every frame.

System Task Code:

```
1 Camera.faceSky = true
2 If PressureSensor1 > 100 // If the sensor is pressed.
3       Sky_color = Sky_color + PressureSensor1 // Increasing the value makes the sky brighter.
4             If Sky_color > Sky_threshold //Checks if the color is greater than the threshold.
5                   Scene_mood = SummerScene //Textures and mood set to summer.
6             If Sky_color < Sky_threshold //
7                   Scene_mood = WinterScene // Textures and mood set to winter.
```

Explanation:

In the sky brush, there are four variables. PressureSensor1 is being constantly updated with the values (ranging from 0 - 255) from the first pressure sensor. The sky_color variable is setting the starting color of the sky. It is set by the designer at the beginning but it is changed during the duration of the brush by the dancer. The Sky_threshold is the number that defines which threshold does the Sky, and the Scene_mood is the variable that gets assigned the chosen mood.

As the sky brush begins, the camera turns to face the sky (line 1). In order for the color change to begin, first the dancer need to apply a pressure greater than 100 to the sensor (line 2). If that condition is met, then the value of the variable Sky_color is increasing, shifting the color of the sky towards a brighter, less gloomy blue. In lines 4 and 5, the system checks if the color change has passed the threshold, thus assigning the Scene_mood a summer scene, or if the threshold has not been reached, therefore resulting in a winter scene (lines 6 and 7).

Process 5: Brush 3 --Mountain:

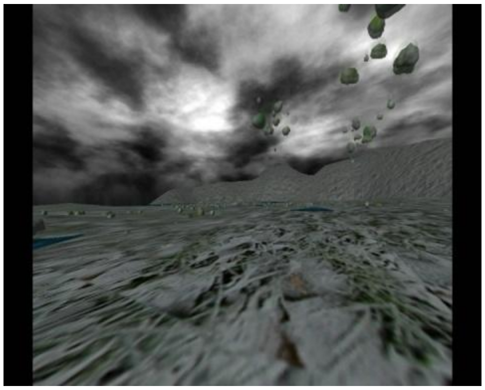
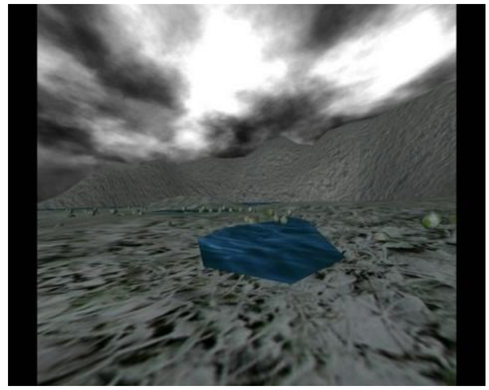
 

Fig. 50 Exploding rocks Fig. 51 Mountain rising.

System Task:

By applying pressure on the sensor the performer can cause random rock eruptions from the ground floor as well as give rise to a mountain. As more pressure is applied the mountain rises at a faster rate. The performer can choose not to raise the mountain, resulting in a flat valley environment. The rocks are generated in a random position, within the vicinity of the space.

System Variables:

PressureSensor1 // The value of the first pressure sensor.
Rock_Class // The rock models (encapsulating methods for positioning and playing back the animations).
Scene_mood // The file containing the mood assigned at the Sky Brush.
Mountain_Class // The mountain model.

Interfacing Technology:

PressureSensor1 = Analysis of the sensors library to calculate applied pressure on sensor 1// Performed every frame.

System Task Code:

```
If PressureSensor1 > 0 // If the sensor is pressed.
        randomPosition.Generate // Generates a random position.
        Rocks.randomPosition //Places the rocks at the generated position.
        Rocks.PlayAnimation // Plays rock animation.
```

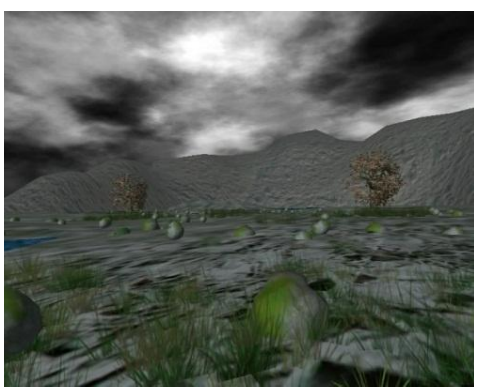
```
5    If SceneMood = SummerScene // Checking if Summer mood was selected during Sky brush.
6        mountain.setTexture = Summer //Setting Summer Textures.
7    If SceneMood = WinterScene // // Checking if Winter mood was selected during Sky brush.
8        mountain.setTexture = Winter //Setting Winter Textures.
9    Mountain.rise + PressureSensor // Increases the height of the mountain depending on pressure.
```

Explanation:

In the mountain brush there are four variables on which the it depends on. The PressureSensor1 is being constantly updated with the values (ranging from 0 - 255) from the first pressure sensor. The variable Rock_Class contains the rock 3d models and encapsulates a number of methods for positioning and playing back the animations contained in the model file. The Scene_mood variable contains the value assigned in the sky brush, which tells the system which mood to follow (Summer or Winter). The Mountain_Class variable contains the mountain 3d model and just like the Rock_Class it encapsulates a number of methods for positioning, texturing and animating.

With the touch of the sensor (line 1) the dancer activated the two classes (Rock_Class and Mountain_Class). As the rocks will appear in both summer and winter moods, firstly the system initializes the Rock_Class. In line 2, the system generates a random position on the floor of the island and subsequently places there the rocks (line3) and plays the rock "explosion" animation (line 4). In line 5 - 8, the system checks the Scene_mood variable to determine which mood was selected and assigns the required texture to the mountain. In line 9, the Mountain_Class is initialized and depending on the duration of the pressure touch, the mountain is raised in the space.

Process 6: Brush 4 -- Grass:



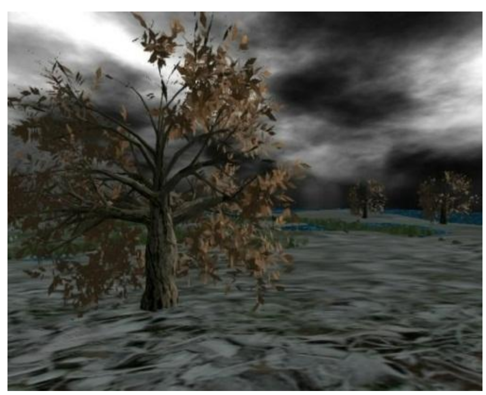


Fig. 52 Rising Grass, Fig. 53 Trees.

System Task:

As soon as this brush is activated, vegetation starts growing on the island. The vegetation grows from random locations and keeps growing until it reaches a certain height and it is beyond the performer’s control. The performer, however, by applying pressure to the sensor can give birth to a tree. The tree also appears at a random location in the vicinity of the space and only one tree can be called every 10 seconds.

System Variables:

PressureSensor1 // The value of the first pressure sensor.//Assigned to CreateTreesEvent.
SceneMood // The file containing the mood assigned at the Sky Brush.
createTreesClass // Event that places trees on the screen. (encapsulating methods for positioning and playing back the animations).
createVegetationClass // Event that places vegetation on the screen (encapsulating methods for positioning and playing back the animations).
generateTree = true // If this value its true, allow the generation of tree. If it's false, do not allow. This will be used to control the rate of tree generation. The performer can only invoke a tree every 10 seconds to avoid over population.

Interfacing Technology:

PressureSensor1 = Analysis of the sensors library to calculate applied pressure on sensor 1// Performed every frame.

System Task Code:

```
randomPosition.Generate // Generates a random position.
createVegetationClass.randomPosition(MaxVal = 100)// Places grass on the island on a random position (max
                                                     100 grass spots).
createVegetationClass.playAnimation //Plays grass Animation.

If PressureSensor1 > 0 // If the sensor is pressed.
    randomPosition.Generate // Generate another random position.
    If SceneMood = SummerScene // If its summer mood.
            if generateTree = true // If 10 seconds past from the last generation.
                createTreesClass.SummerMood // Create tree.
                createTreesClass.randomPosition // Place tree on random position.
                generateTree = False // Turn tree generation off.
                timer = on // Turn on the timer to measure the 10seconds.
```

```
12       If SceneMood = WinterScene
13                     if generateTree = true // if 10 seconds past from the last generation.
14                            createTreesClass.WinterMood // If its winder mood.
15                            createTreesClass.randomPosition // Place trees on a random position.
16                            generateTree = False //Turn tree generation Off.
17                            timer = 0// Turn on the timer to measure the 10seconds.
18 If timer > 10 seconds // If 10 seconds pass.
19       generateTree = true // Turn tree generation on.
```

Explanation:

The Grass brush has five variables. The PressureSensor1 is being constantly updated with the values (ranging from 0 - 255) from the first pressure sensor. The Scene_mood variable contains the value assigned in the sky brush, which tells the system which mood to follow (Summer or Winter). The createVegetationClass contains the 3d nodes of the grass and encapsulates methods for positioning and animating. Likewise, the createTreesClass contains the 3d model of the trees and encapsulates methods for positioning and animation. The generateTree variable is a Boolean value (can only be assigned to true or false) and is here used as a condition test for time duration.

As soon as the grass brush is activated, grass is generated on the island. Lines 1-3 generate a random position, assign that position to the grass and play the grass animation. The next section calls the createTreesClass. Firstly it checks whether it is summer or winter mood (lines 6 and 12) and then creates and positions the appropriate tree (line 8-9 and 14-15). Since it was decided to prevent the dancer from continually planting trees, a method was required to control the time interval between tree generations. This was achieved by using the Boolean generateTree. The system will check and only generate a tree if the variable is set to true (line 7 and 13). As soon as the tree is generated, the variable is turned to false and a timer is activated (line 10-11 and 16-17). When the 10 seconds are over (line 18) then the variable is turned to true again (line 19).

Process 7: Brush 5 -- Nature:

Figs. 54 & 55, Walking tree and rising leaves.

System Task:

In the Nature brush, the scene becomes more mobile. The leaves of the trees begin to move, with some of them drifting to the ground. The performer can call rain with the first sensor or playfully raise the leaves with the second. Stickmen randomly appear in the space, walking for a few meters, looking around and disappearing. This is also the end of the scene. The designer or user is able to switch to wireframe view by the press of a button, as well as fade out the scene.

System Variables:

PressureSensor1 // The value of the first pressure sensor.//Assigned to RainEvent
PressureSensor2 // The value of the first pressure sensor.//Assigned to raiseLeaves Event
raiseLeavesClass // model of leaves (encapsulated with raise command, which raises them and allows them to drop under gravity)
gravity = 9.8 // Gravity
RainEvent // Create particle rain
treeLeaves // Leaves on the tree start moving / falling on the ground
stickMenClass // Call stickmen
wireframeView // Option to turn wireframe view on
fadeOut // Option to turn fadeOut on

Interfacing Technology:

PressureSensor1 = Analysis of the sensors library to calculate applied pressure on sensor 1// Performed every frame.
PressureSensor2 = Analysis of the sensors library to calculate applied pressure on sensor 2// Performed every frame.

System Task Code:

```
treeLeaves.animate // Animate the tree leaves.
treeLeaves.fall(random 30 - 40) // Trigger an event that drops leaves from the trees in a random interval
                                   between 30 and 40 seconds.
stickMen (random(20-30))    //  Trigger an event that makes stickMen appearing on the scene every 20
                                to 30 seconds.
If PressureSensor1 > 0 //If pressure Sensor1 is pressed.
      RainEvent // Activate the rain particles event.
If PressureSensor2 >0 // If pressure Sensor2 is pressed.
      raiseLeaves // Activate the raise leaves event, raising all the leaves from the ground.
```

```
8 wireFrameView = true // Turning on the option to switch to wireframe render.
9 wireFrameView.assignKey (K) // Assigning wireframe to button K.

10 fadeOut = true // Turn on the option to fade to black.
11 fadeOut.timeFrame(5) // Assigning total time it will take for total light fade out.
12 fadeOut.assignKey (L) //Assigning fadeout to button L.
```

Explanation:

In the nature brush there are eight variables which are responsible for what happens during the scene. PressureSensor1 and PressureSensor2 receive data from their respective sensors. The raiseLeavesClass is a variable which encapsulates methods to raise the leaves from the ground and allow them to softly drop in accord to the values assigned in gravity. The variable RainEvent creates a rain made of particles which fall and collide with the island. The treeLeavesClass is a method responsible for animating the leaves on the trees. The stickMenClass invokes little stick men which randomly appear on the island, perform certain animations and disappear. Finally, the wireframeView and fadeOut variables, respectively enable the wireframe and fadeout modes onto the 3d scene.

As soon as the nature brush is loaded, a number of random instances are loaded. The treeLeaves method is called and it starts animating the leaves on the trees (line 1), simulating an effect of wind. Furthermore, the treeLeaves extend to a second function (line 2) where every 30 to 40 seconds, leaves start falling downwards from the trees. The stickMen method is also called (line 3), invoking stickmen to appear on the screen every 20 to 30 seconds. In line 8, the wireframe mode is enabled and then assigned to the key "K" for easy access from the designer (line 9). In the following three lines (10 - 12) the fade to black option is turned on, a time frame is set for it and the button "L" assigned to the function. Furthermore, now the dancer has acquired two new manipulation tools. By touching the first sensor, she can activate a rain of particles (line 4-5) and by touching the second one she can raise the leaves from the ground. By releasing the sensor, the leaves will glide to the ground.

Conclusion and Evaluation

In the last section I have demonstrated seven of the main processes that make up the backbone of the "creation scene". The intention of demonstrating these processes was to explain the logic and reasoning of the system as well as to explain in simple terms how designers prepare and set up an interactional 3d world. My aim here was firstly to document the "creation scene" making transparent the applied methodology to 3d designers interested in investigating navigational spaces with interactional qualities for dancer performances and installations, as well as an attempt to offer a simple introduction of new technologies to artists aspiring to work with a 3d interactive medium. Furthermore, I aim to inspire the artistic imagination and provide them with knowledge based on feasible and functional technological and coding methodologies that would help teams of artists and engineers produce works that might attest to a deeper understanding of technological routines, while minimizing potential miscommunications.

By referring to the seven processes, five points need to be identified and demonstrated which need to be considered by both designer and the team when a project calls for a 3d interactional world in a dance performance. The "creation scene" was created with non-linearity and randomness as the two prevailing themes. As it can been seen by studying the code, during the "mountain brush" the rocks which are generated on the island (code lines 2-3) are placed in random positions. The same is true in the "grass brush", where both the grass (code line 2) as well as the trees (code line 9) are placed on the island on randomly generated coordinates. During the final scene ("nature brush") the stickmen also appear on random locations. The simulated physics in the scene also play their part in randomization, by creating a wind movements which carries the tree leaves left and right. By applying these elements of randomness the virtual world acquires a sense of unpredictability resulting in different outcomes every time the scene is repeated- just like nature.

Non-linearity is ensured by adding a conditional variable which is dependent on the action of the dancer. During the "sky brush" Katsura has the ability to change the sky color from dark grey to light blue (code line 3). Depending on the choice she makes the textures and the final outcome of the island would look different. This contributed again to the unpredictability of the scene, showing how a 3d world can take branches of alternative visual themes.

A third point which needs to be identified is the use of thresholds. In the "cement brush", the dancer is able to break the cement by jumping up and landing on the ground. The system monitors the midsection of the dancer and compares that to a fixed threshold (code line 1). By changing this variable threshold, the dancer will have to make a smaller or a bigger jump to break the cement. The same can be said in applying the "sky brush" where there are thresholds for both the speed of the color (code line 3) changing as well as the hue, saturation and lighting values (HSL) of the sky color. In the "grass brush" a threshold for a maximum a grass needs to be set (code line 2) so it will prevent overpopulating the island, both for visual and technical reasons. Too much grass on the island might make it look unrealistic and also it might slow down the system considerably. A number of these thresholds can be set after consulting both the performers and the rest of the team members as they control both functional as well as aesthetic elements of the virtual world.

As the 3d world is a universe with its own time it is possible to set up a number of timers to control aspects of creation. In the "nature brush" stickmen appeared on the island at a random positions and at random time intervals. A timer needed to be set, to make sure that the stickmen would not appear continuously, thereby over populating the island (code line 3). In order to prevent the dancer from continuously invoking trees, the “grass brush” has a timer, imposing a limit of one tree every 10 seconds (code line 18). Timers act in a way to limit the freedom of the both the dancer and the virtual world, which might be considered controversial in an environment supposed to be under the control of its creator. Unlike traditional game environments, where a player has the capacity to replay and learn from his/her mistakes, this 3d space was partially created for an audience and as a result certain decisions were made to fit with these conditions.

The fifth point which needs to be considered, especially when one aims to create a 3d space with a number of interactive possibilities, is the use of precautionary measures to minimize accidental and undesired responses from the system. In the "cement brush" before the dancer can move to the "sky brush" the system needs to make sure that the cement was completely cracked. Therefore, a variable needed to be set in the "change brush" process, which would only allow a brush shift if the current brush was flagged as complete (code line 2). A further example of a precautionary measure can be found in the "change brush" process. In order for the dancer to initiate a change of brush, the pressure sensor must register a pressure of a minimum of 115. This was set in order to prevent an accidental brush shift (code line 1).

The experience gained working on the "creation scene" demonstrated that these five points contributed greatly towards the fluent interaction achieved by the dancer in the virtual world. Regarding the technological dimension of the various interactional relations in the performance the code can be further extended to include a greater number of choices and more unpredictable results. The performance space can also be more wired up, capturing and sending more information which would allow the system to have a greater scope (perception) of the space. A different camera set up could be used, utilizing perhaps a *kinect* camera which could provide more accurate results which do not heavily rely on the lighting in the space.

By exposing the code, the logic, the variables and the techniques to whole team, a designer might be able to receive valuable feedback while creating the space. A world with interactive qualities needs to be developed in collaboration with the dancer who will be performing. The mood and color of the environment and the thematology of the content need to relate to the work of the rest of the team members (for example costume design and sound scapes) and the greater scope of the conceptual idea.

Furthermore, technical configurations need to be considered as well, such as the physical space (scenography), the lighting of the room and the positions of the projectors. The creation process constitutes collaborations from the initial conception to the final testing and evaluation of the world, therefore exposing the code to the team helps in not only receiving feedback from a number of creative minds involved in the production process but also inspires further methodologies of multi-disciplinary collaborations.

Conclusion

My objectives in this thesis were to investigate the design and creation process of interactional virtual 3d spaces and their potential integration in dance performances and installations. Following the physical nature of dance, a special attention was given in proposing theoretical and technological methodologies for gesture activated and body movement controlled 3d environments. The research framework comprises of an analysis of Mark Hansen's mixed reality paradigm, immersion and navigation techniques as well as an investigation of the current instruments and software. A special attention is given to ensure that the production techniques, the interaction technologies and methods as well as the offered code is clearly documented and explained for both 3d designers wishing to engage the interactive realm as well as team members and performance artists with less technological expertise.

In the immersion chapter, after a brief investigation of the technological possibilities of using current and upcoming technologies in both a disembodied reality as well as in an augmented reality setting, I have analyzed and evaluated immersion techniques used by a number of recent dance performances and installations and proposed to examine immersion methodologies from the computer game medium. In order for a performer to be fully immersed, a material and kinesthetic presence needs to be created inside the virtual space. Interactions need to originate from inside the virtual world by transferring and replicating the whole physical movement of the dancer in its raw form inside the space instead of trying to assign meaning to gestures and movements performed in the physical space. Movement in the virtual space will then incorporate a body with mass and volume which are subjected to the physical properties of the space, creating much higher degrees of agency and consequently, immersion for the perfomer.

Exploring a virtual space in a performance or installation context is different than exploring traditional virtual environments. Unlike games and social network environments, the designer cannot create scenarios which will involve the user in deep, long term commitments. Instead more emphasis should be given in how to make spaces interesting and involving by taking under consideration that the immersive state will firstly, only last a limited time and secondly, will not be repeated. Furthermore, the visualized space should not only be directed towards the attention of the immersant but rather towards an audience therefore the agency of the performer needs to be externalized and visualized.

The virtual world needs to be life-like, living and breathing: a complete ecosystem which does not appear to be created for a brief encounter with the performer but rather a space that creates the illusion that it pre-existed as an alternative realm. The interactions must occur naturally and fluidly, without constantly making the audience search for interactive relationships. Rather, the performer should instill a sense of belonging with the space, where natural movements result in both immediate visible results (first generation interactivity) as well as randomized, non-linear responses (second generation interactivity).

The performers needs to feel a sense of agency towards the space, immersed in both short term goals as well as long term ones, always having a sense of purpose and direction. A simple way to achieve this is to place the virtual world under the context of a larger eco-system, for example by making it part of a narrative structure.

Even though the 3d environment is much more than a visual stimulation for the user, it is however mainly a visual spectacle for the audience. Furthermore, deriving from Kabakov's "total installation" concepts analyzed in chapter 2, the virtual environment can be considered to offer a spatial narrative experienced by the audience as sensorial stimulations caused by the collaborate result of audio/visual cues along with their thoughts and preconceptions. In order to endorse the audience's active participation in the production of meaning, the content of the 3d world as well as the movement of the virtual camera need to include parametric and randomized elements of abstraction. Following the features suggested by Broadhurst as aesthetically prominent within the digital domain, the 3d content of the world needs to appear fragmented and poorly defined, lack uniformity and repeated over time in different varieties and forms. Furthermore, the camera, as in Waliczky's animations, should offer a visual perspective that does not just display the 3d content but rather shape the experience the same way as a person's perspective can shape one's experiences of the physical world.

As a technologically embodied performer moves through the physical space, his or her presence is imposed in two different realms, which come together and forme a hybrid world. The resultant collaboration is not only dependent on the technological interfaces between the two realms but rather on their fluid inter-connected existence. Both worlds need to exist on their own with the performer acting as a connecting link between the two. It is in my belief that future investigations should concentrate more on looking for interaction qualities and meaning in the aesthetic properties of inter-realm spatial sharing and information exchange of two pre-existing worlds, leaving behind worlds and spaces that can only spawn into existence through a performer's input. In chapter 3, an investigation was performed to break down, adapt and theorize 3d virtual world designing and building techniques to accommodate them for an interactive live stage performance context. I proposed a methodology to create evolving, self contained worlds with their own intelligence which allow a technologically embedded performer to form a presence, navigate and interact with them. Building up from Hansen's mixed reality paradigm and Merleau-Ponty's phenomenological ideas about the body image and the body schema – ideas that explicitly give emphasis to the physicality of dance – I proposed the idea of the "space-schema," a system that incorporates a number of processes that can be used as a base to create a real time 3d interaction space.

The theory and methodology was subsequently put into practice in the “creation scene” which was part of the DAP Lab production of *UKIYO (Moveable Worlds)* and acted as one of my case studies. *UKIYO (Moveable Worlds)* is a considerable step beyond my first case study, the dance installation *Suna no Onna*, which introduced me to wearable sensor design and the first stages of interactive animation. In the “creation scene” I was able to include and integrate the proposed immersion and navigation theories and create a world based on my “space-schema” theorem.

The brush system has introduced physical movement working along with the kinaesthetic and audiovisual stimulations to help keep the dancer’s agency and immersion levels at their peak in a constantly moving and evolving world. The dancer was partially existing in a dark, eerie virtual realm, visually represented by a moving camera displaying the Hiroshige inspired 3d landscape in a fragmented, barely defined form, enhancing the curiosity and anticipation of the audience. The world, acting as a mastermind of its own abstraction, worked along with the dancer to randomize and populate the land following closely the dancer's will and intention. Matching the evanescence theme of the production, the *ukiyo* island was created by the dancers body code, formed and shaped through the means of technology, before slowly deconstructing back into digital wireframe code and fading away.

The methodology, techniques, instruments and programming code to create the world have been analyzed in the last section of the *Practice Work* chapter. This code has been also made available for the artistic community for further improvement and experimentation. As it is always the case with creative tools, the effectiveness of the techniques, instruments and code can only be evaluated through the creative work produced by them. My intention in this last section, and as a general theme to the whole thesis, was to offer and explain the underlying knowledge in creating the work, inviting discussion in the potential use of gestural and body movement interfaced virtual 3d worlds.

Bibliography

Ben-Tal, Oded (2008) “Musical Toys: Interactive Audio for Non-Musicians,” Linux Audio Conference Cologne: Germany. (Unpublished).

Bianchi-Berthouze, Nadia, Whan Woong, Kim, Darshak, Patel (2007) “Does Body Movement Engage You More in Digital Game Play?” *ACII '07 Proceedings of the 2nd international conference on Affective Computing and Intelligent Interaction,* 102-13. Springer-Verlag Berlin, Heidelberg.

Birringer, Johannes (2007) “Performance and Science,” *Performing Arts Journal* 85, 21-35.

Birringer, Johannes (2007) “Performance and Technology,” *Danca em foco,* 82-91.

Birringer, Johannes (2008) *Performance, Technology & Science*. New York: PAJ Publications.

Birringer, Johannes/Danjoux, Michèle (2009) “Wearable Performance,” *Digital Creativity* 20:1-2, 95-113.

Biswas, Amitava (2008) “Managing art-technology research collaborations,” *Int. J. Arts and Technology, 1: 1*, 66-89.

Brown, Emily & Cairns, Paul (2004) “A grounded investigation of game immersion,” *Conference on Human Factors in Computing Systems,* 1297-1300. Vienna: ACM Press.

Clarke, Peter Bernad (1999) *Japanese new religions: in global perspective.* London: Curzon Press.

Coomans, Marc (1997) “Towards a Taxonomy of Virtual Reality User Interfaces,” *International Conference on Information Visualisation*, 27-29. London.

Csikszentmihalyi, Mihaly (1997) *Finding Flow: the Psychology of Engagement in Everyday Life.* New York: Basic Books.

Damasio, Antonio (1994) *Descartes' Error: Emotion, Reason and the Human Brain*. New York, NY: G. P. Putnam's Sons.

Davies, Char (1995) “Osmose: Notes on being in Immersive Virtual Space,” Montreal: ISEA '95.

Davies, Char (1998) “Osmose: Note on Being in Immersive Virtual Space,” *Digital Creativity,* 9:2, 65-74.

Davies, Char, & Harrison, John (1996) “Osmose: Towards Broadening the Aesthetics of Virtual Reality,” *Siggraph 96*, 25-28. New Orleans, Louisiana, USA: ACM Press.

De Luca, Alessandro (2009) “Control design and experimental evaluation of the 2D CyberWalk platform,” *Proceedings of the 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 5051-5058. Piscataway, NJ, USA: IEEE Service Center.

Dixon, Steve (2004) “The Digital Double,” in Gavin Carver and Colin Beardon, eds., *New Visions in Performance: The Impact of Digital Technologies.* The Netherlands: Swets & Zeitlinger, pp.13 – 31.

Dixon, Steve (2007) *Digital Performance: A History of New Media in Theater, Dance, Performance Art, and Installation*. Cambridge: MIT Press.

Dove, Toni (2005) “Haunting the movie: embodied interface/sensory cinem,” in Gavin Carver and Colin Beardon, eds., *New Visions in Performance: The Impact of Digital Technologies*, Swets & Zeitlinger Publishers, pp. 107-20.

Dyson, Frances (2009) *Immersion and Embodiment in the Arts and Culture.* London, England: University of California Press.

Fock, Niels (1963) *Waiwai. Religion and society of an Amazonian Tribe.* Copenhagen: The National Museum of Denmark.

Goldberg, RoseLee (1979) *Performance Live Art 1909 to the Present.* New York: Harry N. Abrams, Inc.

Grau, Oliver (2003) *Virtual Art, From Illusion to Immersion.* Cambridge, Massachusetts: MIT Press.

Hansen, Mark (2006) *Bodies in Code. Interfaces with Digital Media.* New York: Routledge.

Kabakov, Ilya (1995) *On the "Total Installation."* Ostfildern: Cantz Verlag.

Krueger, Myron W. (1993) “An Easy Entry Artificial Reality,” In Alex Wexelblat, ed., *Virtual Reality: Applications and Explorations*. Cambridge, MA, Academic Professional, pp.147 – 157.

Loomis, Jack (1992) “Distal Attribution and Presence,” *Presence: Teleoperators and Virtual Environments*, 1:1, pp. 113 - 119.

Magruder, Michael takeo (2009) “*The Vitruvian World*: a case study in creative hybridisation of virtual, physical and networked space,” in Franziska Schroeder, ed., *Performing Technology: User Content and the New Digital Media*. Newcastle: Cambridge Scholars Publishing, pp. 51–71.

Manning, Erin (2009) *Relationscapes: Movement, Art, Philosophy.* Cambridge, Massachusetts: The MIT Press.

Manovich, Lev (2001) *The Language of New Media.* Cambridge, Massachusetts: The MIT Press.

Massumi, Brian (2002) *Parables of the Virtual : Movement, Affect, Sensation.* Durham: Duke University Press.

Merleau-Ponty, Maurice (2002) *The Structure of Behavior*, 7th Printing (trans. A.L. Fisher). Pittsburgh, PA: Duquesne University Press (originally published 1942 in French as La Structure de Comportement).

Merleau-Ponty, Maurice (2005) *Phenomenology of Perception* (trans. Colin Smith). London: Routledge.

Morie, Jacquelyn Ford (2007) “Performing in (virtual) spaces: Embodiment and being in virtual environments,” *International Journal of Performance Arts and Digital Media*, 3:2 & 3, 123-38.

Newman, James (2004) *Videogames.* London: Routledge.

Palumbo, Maria Luisa (2000) *New Wombs: Electronic Bodies and Architectural Disorders*. Basel, Switzerland: Birkhäuser.

Riegl, Alois (1901) *Spätrömische Kunstindustrie nach den Funden in Österreich-Ungarn, Part 1*. Wien: Verlag der K. K. Hofund Staatsdruckerei.

Slater, Mel & Wilbur, Sylvia (1999) "Through the looking glass world of presence: A framework for immersive virtual environments," *FIVE 95 Framework for Immersive Virtual Environments,* QMW University of London.

Stelarc (2005) *Stelarc: The monograph*. Cambridge, Massachusetts: The MIT Press.

Takayuki Iwamoto (2008) "Airborne Ultrasound Tactile Display," *SIGGRAPH 2008 New Tech Demos,* 504-513. New Tech Demos.

Turner, Jeremy (2002) "Myron Krueger Live," *C-Theory,* 1-2, Article 104.

Trifonova, Anna (2008) "Software engineering issues in interactive installation art," *Int. J. Arts and Technology, 1:1*, 43-65.

Wardrip-Fruin, Noah, and Pat Harrigan, eds. (2004) *First Person: New Media as Story, Performance, and Game.* Cambridge, Massachusetts: The MIT Press.

Witmer, Bob & Singer, Micheal (1998) "Measuring presence in virtual environments: A presence," *Presence: Teleoperators and Virtual Environments*, 225-40.

Internet Sources

Birringer Johannes (2006) "Commentary on the aesthetic/technical contexture of the Interaktionslabor 2006 Lab," http://www.ashbulayev.com/wp-content/uploads/2009/07/InteraktionsLabor_Theory.pdf, accessed Feb 19, 2011).

Birringer, Johannes (2005) "New Visions in Performance: The Impact of Digital Technologies," *International Journal of Performance Arts and Digital Media* 1:1, 83-88 (http://people.brunel.ac.uk/dap/visions.html, accessed Feb 19, 2011).

Boym, Svetlana (1999) "Ilya Kabakov: The Soviet Toilet and the Palace of Utopias," http://www.artmargins.com/index.php/archive/435-ilya-kabakov-the-soviet-toilet-and-the-palace-of-utopias, accessed Oct 25, 2010.

Emotiv (2010). *Emotiv*. Retrieved 10 4, 2010, from http://www.emotiv.com/index.php

Kurzweil, Ray (2009, 4 28) "Ray Kurzweil Explores the Next Phase of Virtual Reality." Retrieved 10 1, 2010, from http://bigthink.com/ideas/14533

Manovich, Lev (1998) "The Camera and the World: New Works by Tamás Waliczky." http://www.manovich.net/TEXT/waliczky.html accessed Oct 23, 2010.

Micoy (2007). *Micoy A Real Experience*. Retrieved 10 5, 2010, from http://www.micoy.com/index.cfm

Ross, George Macdonald (1975). *Descartes - Description of the human body*. Retrieved 10 12, 2011, from http://www.philosophy.leeds.ac.uk/GMR/hmp/texts/modern/descartes/body/body.html

Stelarc. (2011) *Stelarc*., http://stelarc.org/?catID=20229 , accessed January 2, 2011.

Szepesi, Anna (1995) *THE GARDEN (21st CENTURY AMATEUR FILM),* http://www.waliczky.com/waliczky_start.htm, accessed Oct 23, 2010.

-. (1995). *Der Wald (The forest),* http://www.waliczky.net/pages/waliczky_forest1.htm, accessed Oct 25, 2010.

TED Speech. (n.d.). Retrieved 10 4, 2010, from http://www.ted.com/talks/tan_le_a_headset_that_reads_your_brainwaves.html

Waliczky, Tamás (1994) *THE WAY,* http://www.waliczky.com/waliczky_start.htm, accessed Oct 25, 2010.

-. (1994) *THE WAY,* http://www.waliczky.com/waliczky_start.htm, accessed Oct 25, 2010.

-. (1997) *SCULPTURES,* http://www.waliczky.com/waliczky_start.htm, accessed Oct 25, 2010.

-. (1998) *Landscape,* http://www.waliczky.com/waliczky_start.htm, accessed Oct 25, 2010.

-. (2000) *The fisherman and his wife,* http://www.waliczky.com/waliczky_start.htm, accessed Oct 25, 2010.

APPENDICES

Suna No Onna

Credits:

Conceived and directed by Johannes Birringer and Michele Danjoux

Performers: Katsura Isobe, Olu Taiwo, Helenna Ren

Costume Design : Michèle Danjoux

Photography :Paul Verity Smith

Digital Animations : Doros Polydorou and Maria Wiener

2d Designs : Jonathan Hamilton

Original music: Oded Ben-Tal

scenography: Hsueh-Pei Wang

Lighting design: Miguel Alonso

Exhibitions:

Saturday 8 December 2007 in Laban Theatre Studio

Re-staging:

March 14, 2008 in Watermans Art Center, London

Documentation / DVD

Photographs (Laban Theatre + Waterman Gallery + Inspirations)

Videos (Performance Extract (8.03 minutes) + A number of clips used in the performance)

UKIYO (Moveable Worlds)

Credits:

Conceived and directed by Johannes Birringer and Michele Danjoux

Audiophonic design, concepts and wearables: Michèle Danjoux

Choreography: Katsura Isobe, Helenna Ren, Anne-Laure Misme, Yiorgos Bakalos, and Olu Taiwo

Choreography on screen: Biyo Kikuchi, Yumi Sagara, Jun Makime, Ruby Rumiko

Interactive animation and interaction design: Doros Polydorou

Photography: Paul Verity Smith

Video Design: Johannes Birringer

Original music: Oded Ben-Tal

Live digital sound and sensor processing: Sandy Finlayson.

Live music composed and performed: Caroline Wilkins

Scenography & lighting: Johannes Birringer

The Second Life graphical interface is designed by Takeshi Kabata and Yukihito Obara

Additional engineering: by Eng Tat Khoo (Keio-NUS CUTE Mixed Reality Lab)

Exhibitions:

June 2010 at KIBLA Media Art Center, Maribor, Slovenia

Re-staging:

November 26th, 2010 at Lilian Baylis Studio, Sadlers Wells, London.

Documentation / DVD

Photographs (Kibla Media Art center + Sadler's Wells + the filmshoot)

Videos (Sadler's Wells + Kibla Center + Compositing version + animation of creation scene)