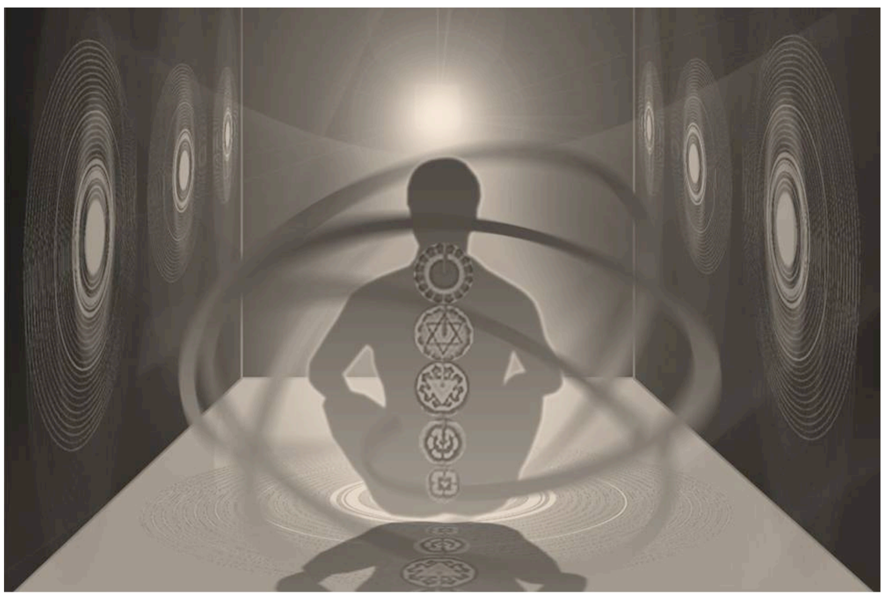
A Framework for Interactive Sonic Design into Architectural Spaces

by

Stavros Didakis



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Abstract

Time and space are two phenomena that have been investigated the most over the centuries, although their association still remains a mystery. However, they need each other to exist; time cannot occur without space, and space is meaningless without time. Sound and architecture are directly related with time and space accordingly, and the practices of these art forms many times foresee the fusion of their spectra. The importance of this correlation is high as it may provide a way to experience and inhabit spaces alternatively, enhance our wellbeing, and elevate our state of mind. This thesis provides a framework for the design and implementation of sound into architectural spaces, using flexible, modular, and effective software programming techniques. Moreover, socio-spatial information is closely observed and analyzed into control parameters that define interactively the sonic elements, and the ambience they create intends to form an improved perceptual space.

Dedication

I dedicate this work:

To my beloved mother that left us early

To my family, and the newborn babies that will fill with joy our lives

And to Maria, for her individuality, comfort, and love, I experience life alternatively

Acknowledgements

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Chapter 1: Introduction

> ‘*The Architect should be equipped with the knowledge of many branches of study and varied kinds of learning, for in the architectural judgment all of the work of other arts is brought into test*’ (Vitruvius, 1960).

Motivation

For a long time now architecture is approached as a physical object, made with solid materials and a purpose to remain silent in stasis. However, this is not the case anymore as buildings can facilitate further functions that re-contextualize the architectural practice and establish a new symbol of cultural communication. These functions accommodate more flexible and imaginative aspects for the design and development of a space that is focused not only on the visual domain, but also evoke a number of sensorial modes, which can transform the understanding and comprehension of our environment accordingly.

The power spaces have to shape our personality, memory, and experience, is a matter of importance and it may affect drastically many psycho-physiological responses of a person. According to this reason, architectural practice needs to provide harmonious environments with relaxing atmospheres in order to smooth tension and anxiety, and same time create dynamic conditions that are able to alter either our perception about the space or the space itself. New dimensions of thought propose ways for varying and adapting functionality into living architecture, creating possibilities for interactive communication, or even further expression of intellectual and emotional states.

Evolution is always shifted according to the technological advancements that also change the infrastructure of the society and the way our brains function and perceive the surrounding world. Novel trends of the digital and sensor technology have been developed to create new forms that register fluidity by defining the atmosphere, changing the architectural structure, or altering the spatial perception. A significant matter has become the need to accommodate human desire, and calibrate our environment with custom interfaces that are even more creative, supportive, and efficient.

The ethereal nature of sound has the power to penetrate our bodies and minds, and sonic adornments have the ability to give richness and texture to the architectural space, a consideration that enhances aesthetics, creates pleasant moods, and conveys significant meaning. Since digital technologies have become the determinant mechanism in architectural design, it is easier to realize sound as a flexible material for the attainment of perceptual and emotional engagement. According to this, digital technology can be used for the sonification of an environment as a way to redefine the aural identity, and adjust our lifestyle into the evolutionary process of inhabitancy.

In the present thesis I explore the relationship between sound, architecture and interactivity, and I seek ways to approach the sound design as a vehicle for communicating and affecting aural awareness, experience and perception. In order for such vision to be realized, a system that is coherent, functional, adoptable, dynamic, and flexible needs to be devised. For this reason I have developed a *Computer Vision Analysis* system that processes and analyzes socio-spatial information like motion, presence, position or circulation, to determine measurable data for the distribution into the *Sonic Architect*, a software program that statistically analyzes the incoming information, and creates control parameters for sound design in an easy, efficient, and configurable way. The system intends to become a framework that enables the discovery of strategies for the sonic beautification and design of a space.

The objectives that I am mostly interested at, concern the ways architectural spaces can be sonified; that is to provide a sonic environment that is relevant to its contexts and has the ability to enhance our perception and our well-being. I explore strategies for sound design that is approached as a function of architectural practice, so that it relates to aesthetics, compatibility and operation, in such a way that does not violate the setting, the context, or the inhabitant that co-exists with them. Moreover, I consider the fact of interaction and sensor implementation, feature extraction and mapping to the parameters of sound that needs to behave in relation to the space it occupies. Finally, I try to observe and criticize if this concept may enable a new state of consciousness according to both practices of sound and architecture.

In summary, the proposal of this thesis is to integrate sonic design into the architectural formation, and treat sound as an important ingredient for the construction of a setting. Therefore, it would become possible to define further expressional qualities to every environment, convey meaning and information, and also transform inhabitancy into a fascinating and engaging experience.

Overview

The remainder of this thesis is organized into five chapters. Chapter 2, Background, presents attempts from artists and composers to define the relationship between sound and space. Aspects of aural architecture are discussed, as they become a determinant mechanism to the behavior of sound in an architectural space. Finally case studies are investigated that consider sound as an important design element to their responsive architectural context.

Chapter 3, Methodology, presents philosophical and psycho-physiological matters that are important to the positive enlivenment of architectural spaces. Moreover, this section proposes strategies for the sound design of the environment, considering aspects such as aural and social context. Methods are mentioned for the selection of the sound material, and how specific stimuli affect people's perception. Furthermore, interactivity as an aspect of the sonic design is described, and approaches to extract information from the environment are shown. Finally, a research questionnaire that has been devised for the purposes of this thesis is discussed.

Chapter 4, System Development, presents a software framework for the sonic design and analysis of socio-spatial information. The chapter analyzes the architecture of the system that uses computer vision techniques, statistical analysis methods, and a number of sound modules to create an autonomous system. Also, there is an analysis concerning the programming strategies that have been followed, and services that it provides to the user are presented and evaluated.

Chapter 5, Case Study, presents an installation that has been developed with the use of the aforementioned system in the main hallway of the Royal Victoria Hospital in Belfast. In this chapter, methods are shown that have been followed for the sound design of the space, and how the interaction is transformed into sonic adornments that surround the space and the listeners. Results from the installation and the design methods are also mentioned.

Chapter 6, Conclusions, includes a discussion about considerations that were involved during the development of this work, as also clarifications on methods that have been followed on the proposed system. Furthermore, future developments and ways to enhance system's functionality are stated. The chapter concludes with an overall evaluation of the entire process, and summarizes the achievements and the importance of this work.

Finally, in the Appendix section I present further information about the thesis, such as the research questionnaire and its results, and also a relevant interview. Moreover, there is a detailed explanation of the user-interfaces of the software systems and also a detailed analysis of the soundscape components of the installation in Royal Victoria Hospital.

Chapter 2: Background

Introduction

The process of feeling and listening the environment we occupy has the power to extract information and understanding, in a similar amount the mechanism of vision does. But is it possible our senses to be influenced by the spatial organization of the environment, its light conditions, or in our case by the way sounds are articulated and distributed? Can our perception and experience be transformed according to the sonic events that exist in the space? Responsive architecture may provide answers and flexible conditions for the design of even better living qualities, however it is still unknown what is the extend to this 'responsiveness', and how much the technology and the digital medium can accomplish for the creation of personalized and effective environments.

The following chapter addresses all these issues that have been followed from different practices and contexts. However they are all related to the way sound and architecture behave collaboratively. The main purpose of this chapter is to create spherically an informative background concerning the collision and integration of sound into architectural spaces from a semantic, cognitive, artistic, spatial, and technological perspective.

Sound and Space

> '*Indeed, whatever the affectivity that colors a given space, whether sad or ponderous, once it is poetically expressed, the sadness diminished, the ponderous lightened'* (Bachelard, 1994).

The relation between sound and space is inextricably connected, as each one performs the other, 'bringing aurality into spatiality and space into aural definition' (LaBelle, 2002). Spaces redefine and shape the acoustic attributes of sound, although this shaping can also work the other way around, as the 'poetically expressed' space can transform experience and perception. This symbiosis needs to be approached in an efficient and creative way so that new conceptual proximities and functions will emerge. The relation has to demonstrate conversational events between space and aural perception and needs to redefine architectural form making as an even more expressional process.

The invention of the telephone in 1876 by Alexander Graham Bell and the invention of the gramophone in 1877 by Thomas Edison created a new state of awareness and a 'formation of [a] modern sound consciousness' (Thompson, 2004). The displacement of sound in time and space was now possible, as the ethereal nature of sound could be captured, transformed and manipulated through electric circuits and wires. The acoustic energy was liberated from the past and the present, and could live in a distant time and place. A few decades later, artists and engineers begin to see the power of these new media, and start experimentations on the ways these devices can alter our perception and moreover our lives.

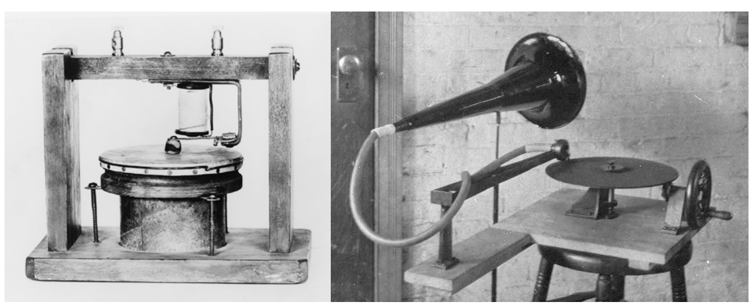


Figure 1 – Pioneering Devices: Telephone and Gramophone

(First Telephone, 2007; Gramophone, 2007)

Christine Kozlov explores the relation between time, space and sound with the installation '*Information: No Theory*' in 1970. In this work, tape loop recordings are used to combine sound and space in a social context, and to create an environment where the sounds of the near past are heard in the present, and same time the sounds of the present are recorded and played in the future. This sonic environment creates a time-defined anticipation between the participants, the architectural space, and the acoustic events. The recording technology becomes an important aspect of the actual event itself, and as Baudrillard observes: ‘the very definition of the real is that of which it is possible to give an equivalent reproduction’ (Baudrillard, 1983).

Figure 2 – I am sitting in a room

(Alvin Lucier, 2007)

Alvin Lucier in the same year investigates the way technology can be used to redefine the physical relation of sound and space with his work ‘*I am sitting in a room*’ (Lucier, 1990). The piece is performed with the composer sitting inside a room where he speaks a text while his voice is recorded on tape. The recorded passage is played back again in the room and then re-recorded again a number of times. During every process, the room resonances and the electric distortion create a shape alteration to the sound, which results into a conversational interaction between the spatial acoustic attributes of the room, the sound source, and the recording medium.

As it becomes apparent, hearing attentively sounds in space one can detect the shaping process between this interaction and the inheritance of the physical characteristics of the room into the reverberant properties of the sound. Stuart Jones argues that ‘this dynamic sound-event-space relationship means that although one may see space as an object, one other may hear it as activity’ (Jones, 2006), and consequently this relationship needs to define a semantic vocabulary for the communication between sound and space.

Aural Awareness

> ‘*Buildings are never silent, nor they have ever been. The crash of the portcullis, and the chains of the drawbridge in castles, the creaking of cottage shutters, the quiver of air-conditioning, the glissandi of outside lifts suspended from facades, etc.*’ (Delage, 2002).

This passage describes the way Bernard Delage experiences and perceives aural awareness; that is the conscious understanding of the acoustic environment of the spaces we occupy. Each space has the attribute to physically contribute to the shaping of the sound characteristics and create sonic events such as enveloping reverberation, amplitude alteration, resonance, and localization cues. To hear a space involves the active listening process in order to understand how buildings form their sounding environment, and as Rasmussen agrees, important information of the space can be derived from the radiation of the sound waves that exist within (Rasmussen, 1959). This information may involve spatial arrangement and organization, physical material and substance, symbols of culture and authority, as also artistic, technological, social, and historical contexts.

Unfortunately the average listener may find difficulties to aurally perceive the architectural space or identify all the subtle characteristics of the acoustic environment (Reed, 2000), as this process involves attentive and focused listening. However, the acoustic energy of an environment has the power to influence 'both directly and indirectly the mood and emotion of those who occupy or live within a space' (Blesser & Salter, 2007). For this reason sound may create better conditions between buildings and people, in order to craft an aural awareness that is more effective and responsive.

Such an example is the *Cylindre Sonore*, a physical construction designed by Bernard Leitner, and situated in the Parc de la Villette, in Paris. The intention of this space is to redirect and highlight natural sounds with electro-acoustic means, and to enable aural awareness and excitation to the visitors in such a way that their experience and perception is enhanced. *Cylindre Sonore* presents an architectural concept where sound is treated as an important ingredient, and 'its 'spatial boundaries have relevance only as they unfold, transform, or superimpose the experience of sound' (Martin, 1994).

Figure 3 – Cylindre Sonore, Paris

(Cylindre Sonore, 2007)

This proposes a way to transform the acoustic potential 'through the structural, formal, and material characteristics of the architectural design' (Dorsey, 2002), and also demonstrates a way for the sonic elements to become 'a building material in the creation of space' (Martin, 1994). Moreover, this collaboration has the power to effectively communicate meaning to the listener, and transform the listening process into something surprising and unexpected.

Sound Art

A form of art that considers sound as a medium to convey meaning and information such as poetic or artistic perspectives on a space is sound art. The practice of this art form is mainly focused in the way acoustics and psychoacoustics creates alternative experiences of the sonic environment. A necessity to define ways for the transformation of the aesthetic, functional, or artistic aspects of a space has driven many artists such as Max Neuhaus and Bill Fontana to investigate the integration of music and sonic design into public spaces and architectural buildings. Neuhaus has made numerous 'sound installations' (a term he originally invented) at the Times Square (New York: 1977-1992), the Museum of Contemporary Art (Chicago: 1979-1989), the Whitney Museum of American Art (New York: 1983), and in many other sites as well. Neuhaus is mostly interested in the 'design [of] sounds to fit spaces' (LaBarbara, 1977), and also he is concerned and fascinated with the construction of sonic material and distribution into space, either physical or virtual, in order to communicate information, increase aural awareness, and alter memory and spatial perception (Neuhaus, 1994; Neuhaus, 1995). The majority of Neuhaus' works try to create a space where sound needs to be discovered, and also to expand the range of sound possibilities that may occur in a space.

Bill Fontana takes a slightly different approach into his projects, as he uses environmental sounds from a specific site and transmits them into another distant location in order to evoke memory and visual imagery. Rudi (Rudi, 2005) describes Fontana's work as a way to re-contextualize the sonic environment by this masking phenomenon of the naturally occurring sounds. The sonic worlds that are projected, attempt to create a new awareness of the acoustic environment and furthermore to remind the power of sound. One example is the *Sound Island*, an installation developed in the Arc de Triomphe (Paris: 1994), where sounds transmitted from the Normandy coast were projected into the monument with the use of loudspeakers (Fontana, 1996). This articulation of a new sonic space creates an unimaginable and 'unexpected sense of place, time, memory and dimension' (Fontana, 1996). Moreover, the placing of sonic material to where it does not belong or expected, is able to affect perception, listening and experiencing, and thus create a context in which sound is impossible to ignore.

The implications of these sound-works contribute to a state of aural awareness, and for a case where sound becomes an important medium to the distribution of information between the space and the listener. Alternative approaches to the relationship between sound and space have been also considered from composers that try to explore how perception about a space can be altered with the use of musical or sonic material.

Composing for Spaces

Among the first pioneer composers that forecasted the significance of the sound-space relation, was Edgard Varese (1883-1965). Varese, who originally coined the term 'organization of sound', was mostly interested in the ways that sound can be projected through time and space. His electronic music composition *Poem Electronique* was presented at the Expo '58, and was specifically created for the Phillips Pavilion exhibition hall, a modern art architecture designed from Le Corbusier (1887-1665), and Iannnis Xenakis (1922-2001). The result of the installation was 'a prototype of a spatial art where the architecture, color, images, voices, and music, were all superimposed to create an experience far greater than the components' (Blesser & Salter, 2007).

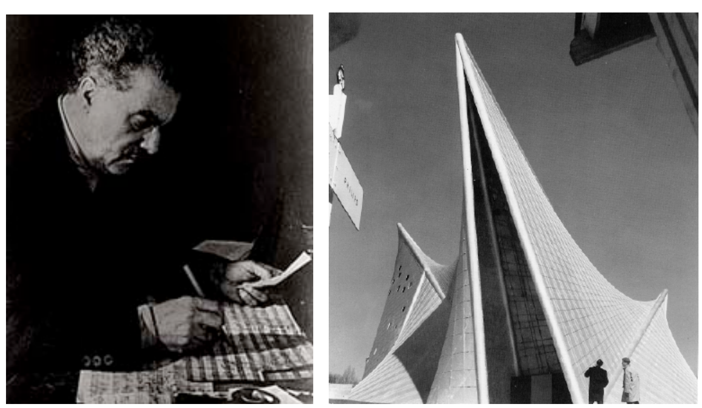


Figure 4 – Edgard Varese and the Philips Pavilion

(Varese, 2007; Philips Pavilion, 2005)

An important consideration for the construction of the system was to create sound motion around the listeners, and enable sound distribution and rearrangement through space (Tak, 1958). The effectiveness of the system was quite remarkable, and the result was the literally projection of music into space.

Another approach to the musical design of spaces has been considered from Brian Eno with his installation 'Music for Airports' (Eno, 1978). The sound articulation of this work involved artistic and poetic reflections concerning the relation of the context with people's experiences, and also with the functionality and the communicational character of the space (Eno, 1996). The vision of the artist was not only to create a 'frozen' music as in the case of *Muzak*, but in addition to construct a sonic environment that connects physical and virtual boundaries, and to provide a state of relaxation and contemplation to the travelers or the occupants of the airport.

Figure 5 – La Guardia Airport, New York

(La Guardia Airport, 2007)

The installations that have been applied to these spaces have variable functions and contexts, and try to endow architecture with the employment of spatial layers crafted through the use of sound. A meaningful interpolation between sound design and architecture needs to occur so that both are experienced as one coherent medium that can improve the quality of life and enhance our wellbeing. Sonic and spatial relations need to be considered in the architectural design, and ‘architecture would have to rethink itself: not as a resonant chamber or concert hall, but as a kind of sonic vehicle’ (LaBelle, 2002).

Interactive Trends

> ‘*Even the most seemingly alienating of technological forms can soon become absorbed within our symbolic horizons, such that no longer appear alienating*’ (Leach, 2002).

Architecture is the art and science of the design, arrangement and manipulation of the physical properties of space, and important consideration to this practice is to offer functional descriptions with aesthetic sensibilities. Sound can co-exist with this consideration, and has the power to create dynamic conditions for the reconfiguration of the space according to the human needs. Recent trends in architectural practice are involved with the use of new tectonic materials, sensor interfaces, and other dynamic systems that morph the architectural space 'into an organism capable of conveying message using various media, integrating them into the building fabric' (Puglisi, 1999). As a result transparency and interaction is achieved, and the structure becomes able to 'flex like the muscles in the body, minimizing the mass, shifting the forces with the help of a nervous system based on electronic impulses, sensing environmental change, and recording individual requirements' (Rodgers, R., cited in Puglisi, 1999).

These transformations introduce new dimensions of thought, and spatial, sound, and light conditions are characteristic elements that can be tuned accordingly to alter physical or ethereal substances, giving the opportunity to construct shifting processes for the attainment of desired inhabitancy. Several approaches have been considered to facilitate buildings that serve people – and not the other way around – providing even more sensitive interactive utilities that 'will prolong our sense of freedom and possibility' (Rushkoff, 2002).

Figure 6 - Aegis Project

(Aegis, 2006)

An approach to the design of interactive architecture has been taken from the MIT Media Laboratory that created the *ambientROOM* (Ishii et al, 1998). The space becomes a computer interface able to receive and transmit information with the use of sensors and physical objects that exist in the space. Sound is an important ingredient to this development, as it becomes a path for bi-directional communication, and also a provider of relaxation with the use of natural soundscapes played through loudspeakers.

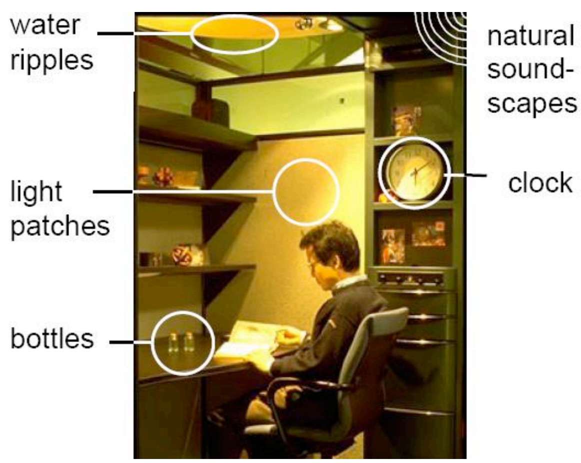


Figure 7 – The ambientROOM

(ambientROOM, 1998)

The construction of specific sonic ambiences that are incorporated into the environment with the use of the digital technology is a way to redefine the identity of a space with great flexibility and adjust to a more responsive and effective lifestyle. An intersection between sound, architecture and interactivity, has been created in the Medical School Library at Queen Mary University, in London (Scott, 2004). The

Ambiguous Object is a massive pendulum suspended from the centre of the oculus in the roof of the building, and its movement together with the sound emitted through space, create interactive elements for the composition of sound. This installation becomes a way to see architecture in a different perspective although the context of the space remains undisturbed and uninterrupted, and at the same time the sonic information can 'be interesting and enriching to those who like to listen to it actively' (Scott, 2004).

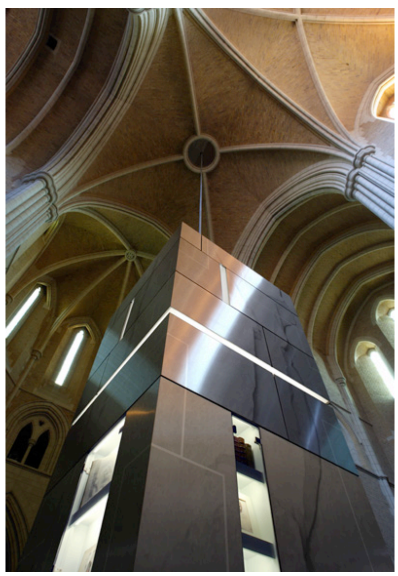


Figure 8 – An Ambiguous Object

(Surface Architects, 2006)

Another work that has similar characteristics and combines architectural structure with interactive sound composition and sensor technology is the *Son-O-House* developed by NOX architects and sound artist Edwin van der Heide (NOX, 2004; van der Heide, 2004). The eccentric metallic structure of the space intends to attract visitors to experience the sonic environment that is synthesized in real-time, creating sonic areas of interference that depend on the amount of movement that is tracked inside the space.

Figure 9 – Son-O-House, Son en Breugel

(NOX, 2007)

This allows a person to 'not just hear sound in a musical structure, but also [to utilize the architecture and its functions] as an instrument, score and studio at the same time' (NOX, 2004). The information that is tracked from the physical world is statistically analyzed, and rules and conditions define the way sound is generated and distributed. The installation intends to provide a space for relaxation, and additionally to create a collision between architecture, sound, physical presence and movement.

The following example is an interdisciplinary project that investigates the implications of brain-like technologies in correspondence to social behavior, architecture, and immersive multimedia environments. *Ada* (Delbruck et al. 2003; Eng et al. 2002) is an ‘intelligent’ room presented as an interactive installation for public entertainment. Multi-modal sensors receive visual, audio, and tactile information from the participants, and the system uses brain-like processes to evaluate the results and present emotional states (Eng et al., 2002). *Roboser* (Wassermann et al. 2003) is a musical system that the room employs to express itself musically, and the program gives the ability for the synthesis of musical material in real-time creating a 12-voice behavioral mode soundscape.

Figure 10 – Ada, an Intelligent Space

(Ada, 2007)

A space that integrates ‘high level of behavioral integration and time varying and adaptive functionality’ (Bullivant, 2005) as in this case, defines the way a person feels and reacts inside this setting. It is a fact that ‘by means of the mimetic impulse the living being equates himself with objects in his surroundings’ (Adorno, 1997), and this mimesis ‘dictates that we are constantly assimilating to the built environment’ (Leach, 2002). New approaches that ‘register fluidity’ (Goulthorpe, 2002) may be introduced as in the aforementioned examples that consider not only the spatial boundaries but also ‘the nature and quality of their interaction with the sounds surrounding them’ (Dorsey, 2002). This relation between sound, architecture and technology, becomes a case of exploration using imagination and creative contextualization.

The architectural space has the power to become an expressive art form that escapes normal functions, and communicates information inside a social context. The sonic adornments are a valuable consideration for the enhancement of the artistic and aesthetic properties of the space as they can create pleasant or reflective moods, and moreover they have the ability to personalize the space by producing attributes that give richness and texture to the architecture. Sound designers have to develop the desired sonic elements according to the concepts and the vocabulary of the culture that is involved in each particular framework, so that artistic and social coherence may be obtained.

Chapter 3: Methodology

> ‘*What we observe is not nature itself, but nature exposed to our method of questioning*’ (Heisenberg, 1958).

In the previous chapter the relation between sound, space, architecture and interactivity attained required information for the integration of sonic design into architectural spaces. In order to continue this study, a methodology needs to be established that may give the benefit to indoctrinate practical applications. Considerations about the sonic environment are presented in relation to psycho-physiological studies, sociological factors, design strategies, sound material selection, and other issues that need to be established if good environments are to be provided.

Tastes of Architecture

An important consideration to the practice of architecture is to create spaces that have the power to influence behavior and perception and also to communicate intelligence and emotion. Studies in Environmental Psychology have proven that architectural and interior design affects physiological and biological reactions (Terman, 1988), influences moods and cognitive performances (Jasnoski, 1991), and also determines in a great extent our behavior (Barker, 1968).

Figure 11 – MODAA Building

(MODAA, 2007)

It seems that we replicate internally the environment we live in, influencing our behavior in such a way that becomes unnoticed to us anymore. A good or bad environment creates good or bad experiences, and through time the shaped memories define a pattern that affects our mood, attitude and behavior. The level of arousal of a space needs to be in a balanced position, so it is ‘neither so low as to court boredom, nor so high as to invite anxiety' (Gallagher, 1994), and also it is important to consider 'not only the level of stimulation [the environment] provides, but also what that means to the person experiencing it' (Suedfeld, 1980).

Figure 12 – The Human Mind

(Human Mind, 2007)

Eastern practices like Feng Shui are involved with the study of individual spaces in order to create a harmonic arrangement of an environment that provides a better flow of energy (*chi*). A space that is designed to provide a good *chi* is 'neither boring nor aggregating but promotes the right level of arousal' (Rossbach, 1983). Feng Shui's main concept is that 'living in harmony with your environment can improve your life', and this setting can attract us and 'make us feel easy in body and mind' (Rossbach, 1987). Disciplines as such are used many times for architectural planning, and they attempt to create specific ambiences in balanced urbanized environments.

This becomes a significant consideration to the architectural practice, as also the member countries of the World Health Organization declare:

> '[…] *The improvement of the health and well-being of people is the ultimate aim of social and economic development*' (WHO, 2007).

Spatial arrangements and sound design are equally important considerations for the construction of a space, and designers must bear in mind both conditions for the creation of even more supportive and personalized environments. The acoustic nature of a space provides a significant perceptual cue, as the auditory stimuli are directly related to the processes of the nervous system, often having an unsuspected influence on our wellbeing. These psycho-physiological impacts have the power to influence moods and associations, and 'although we may not be able to be consciously aware [of], is itself a sensory stimulus that we react to it' [Blesser & Salter, 2007]. Thus, new and exciting sonic spaces should be created that 'induce such feelings as exhilaration, contemplative tranquility, heightened arousal, or a harmonious and mystical connection to the cosmos' [Blesser & Salter, 2007].

Designing Soundscapes

The study of sound design into architectural spaces is a discipline that involves the investigation of various phenomena, such as the natural soundscape of the environment, which is an important consideration to the closer observation of the space and to the definition of its properties; either acoustic, sonic, or poetic. The soundscape – a term originally coined by Murray R. Schaefer – relates to the sound (or acoustic) energy that exists inside an environment, either physical or virtual. Everything that produces sound is considered an important element of the soundscape, so it is logical that the individual listener and participant to become also a 'part of a dynamic system of information exchange' (Truax, 2001). The relationship between the occupants, or 'living organisms' and the environment itself, characterizes its acoustic ecology, a feature that can influence mood and behavior.

Strong components to the character of every soundscape are noise and silence, two attributes that affect the way we feel, experience and perceive an environment. Noise is approached as an artifact that needs to be reduced, or even eliminated, as studies support the argument that it is hazardous to health (Passchier-Vermeer & Vermeer, 2000), it can cause physiological effects like hearing loss, stress, fatigue, and sleep disturbance (Frykberg, 1999), it affects negatively our behavior especially in urban settings (Moser, 1988), impairs the quality of living (Bronzaft et al. 1998), and also creates unbearable or even tragic conditions for symbiosis (Slapper, 1996).

This sonic pollution has the ability to 'disturb the perceived balance of the soundscape' (Truax, 1978), however, many times this feature may have practical approaches, such as the injection of noise into an acoustic arena in order to provide 'the exercise of sonic power' in a 'social or political, autocratic or democratic, supportive or destructive' context (Blesser & Salter, 2007). Noise disturbance generally draws listeners' attention more easily, so it can be applied as a 'pedagogical way into the subject' (Karlsson, 2000) as a way to increase aural awareness and temporal engagement.

In cases where noise is unwanted, methods need to be found to transform and use noise creatively, effectively, and with important cognitive, aesthetical, or engaging implications to the inhabitants. The focus should not be to reduce or eliminate all noisy sources per se, but rather to gain 'knowledge and understanding of the soundscape as a whole, its meaning, its behavior, and all living beings' behavior within it' (Westerkamp, 2000).

Silence, on the other hand, is an acoustic phenomenon that is characterized by its emptiness and for the absence of acoustic energy. However, silence is an important condition to reach a state of contemplation, a moment of inner enlightenment, awareness, and exploration. It is used many times in meditation and religion as a way to connect with the spiritual forces of the universe. In modern urban societies, silence is a condition hard to find, and ‘possesses striking similarities with those aspects of life and community such as unpolluted water, air or soil that were taken as normal and given’ (Franklin, 2000). It is very critical to understand the significance of silence, as it is ‘a key to our personal and cultural sensitivity, both acoustically and socially’ and ‘if we lack sufficient silence, we fail to appreciate or understand its ecological and communicative significance’ (Miller, 2000).

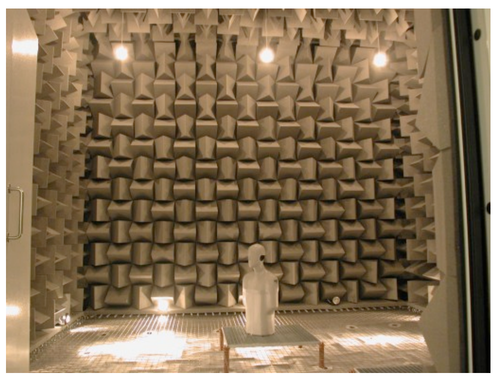


Figure 13 – Anechoic Chamber, Aalborg University

(Anechoic Chamber, 2007)

John Cage’s piece *4’33*, is a contribution to the nature of silence, and builds a perspective where silence becomes only a way to listen carefully the subtleties of the acoustic environment, as there is always ‘something to hear’ (Cage, 1961) even in the quietest spaces. However, many times silence does not attract favor or positive engagement, as it happens inside the un-reflected surfaces of an anechoic chamber for example that create an unfamiliar feeling to most of the people who experience its acoustic, or rather non-acoustic properties. Psychological and physiological problems may be noticed such as discomfort, nausea, or disorientation, resulting in a negative, unwanted effect.

The role of the sound designer is to study the nature of the sounds, understand the rhythm of the soundscape, observe the ways sounds behave collectively, and try to 'discover principles by which the aesthetic quality of the acoustic environment of soundscape may be improved' (Schaefer, 1994). Lex Brown (Brown, 2003) has proposed a plan for design and management of a soundscape that summarizes in understanding the activities of each place, identifying the sounds that should be controlled, maintained, enhanced or eliminated, measuring and predicting the acoustic patterns, and providing information on the establishment of the proposed sound design for the particular place and context.

It is vital to comprehend the needs and opportunities of each specific site as also the 'community that inhabits it' (Coburn, 2002). The designer needs to live inside the space and understand its character and its idiosyncrasies, as its context 'is not only aural, but also visual and social' (Neuhaus, 1994). A correctly defined soundscape creates relations between itself and the context of the environment that many times is relevant to sociological factors like culture, history, economy, and technology. Moreover it t is important to create imaginative distribution of sounds and engaging atmospheres that may enhance the perceptual qualities of the space, ‘draw attention to the physical and sonic characteristics’ of the environment, and also ‘encourage attentive listening’ (Elff, 2004).

However, it is not yet possible to communicate a direct relation of sound information to the listeners, for the reason that no semantics have been defined to enable a relation as such. Specific sonification created from the designer to convey a precise meaning, fails to represent the exact image to individual users, especially when their cultural background varies enough. This means that ‘without conscientious efforts to approach environmental sounds with some imagination and a sensitive social awareness, the language for copying with the everyday sound world will remain crude and ineffectual’ (Copeland, 2000).

Richness and diversity are significant factors to the construction of the sonic environment and the designer has to appreciate the bizarre, noisy, or silent qualities of the space, and manage the stimuli of its artificial soundscape in a way that coherence and balance is obtained. New and exciting sounds should be introduced and used in equilibrium, eliminating monotony, or at the other extreme illogical variation. These sounds need to be closely observed because they are more than just oscillations; they are ‘part of the biological, social and spiritual fiber [and] need to be considered if good environments are to be provided’ (Hedfors, 2003).

Sound Material

‘The contribution made by listening varies greatly among individuals and cultures’ (Classen, 1993), and its subjective nature makes it harder to define rules and conditions as it depends heavily on culture rather than the biology of hearing itself. Different opinions in taste, culture and experience, make the selection of sound material quite complex, as subjectivity remains a mystery and it is impossible to know how cognition processes auditory information to create perceptual features. However, studies have shown that there are sounds able to trigger specific representations to the human brain.

Positively rated sounds include water soundscapes (Carles et al., 1999), natural sources such as insects and birds (Anderson et al, 1983), or other natural sounds like frogs, wind movement in trees and grasses, wind chimes, streams and sea waves (Tamura, 2002). Other sounds that people have certain font of, include social soundmarks of the city like church bells, whistles from ships, sounds from fireworks and festivals (Tamura, 2002), and also human and domestic animal sounds that may be considered neutral (Anderson et al, 1983). Negatively rated sounds include sounds of excessive noise and loudness like garbage collection trunks, noise from nearby neighbors, sounds from the traffic (Tamura, 2002), and generally mechanical and engine sounds (Anderson et al, 1983). Other findings show that sudden acoustic disturbances affect negatively the subjects, and many times rapid disorientation is experienced (Carles et al., 1999). To some extent, the soundscape of an environment has the power to affect many perceptual levels. Expectations may be created about a place, able to affect the tolerance of noise and appreciation of the acoustic space, as particular qualities of the sound can influence the overall evaluation of a setting: 'Sounds would have a constant effect, regardless of the site: singing birds will enhance any location where they are heard' (Anderson *et al.*, 1983).

In this present work, a collection of audio files has been created according to the aforementioned studies. It was important to produce a library of sounds that can be used for sonic design, and due to the reason of subjectivity and diversity of opinion, these sound files have been modified in a number of ways in order to construct a more colorful sonic palette. Each sound has been edited, processed, and modified with the use of *Tapestrea* (Princeton, 2004), *Metasynth* (U&I Software, 2006), and *Nuendo* (Steinberg, 2007). The sounds range from natural environments to more social, mechanical, urban and noisy soundscapes, however, they all present interesting aspects of specific ambiences that are relaxing and may enhance the perception and the way we experience an architectural space. Their implementation in this work gives the benefit to the designer for experimentation in relation to different contexts and subjects. Connections between the sonic stimuli and the inhabitants' experiences are possible to be defined, and furthermore apply rules and conditions to more universal sound design strategies.

Feature Extraction

In order to 'enliven our relationship to the fixities of built space', the 'fluid spaces of sound and interactivity' (Neuhaus, 1994) need to be defined first. The way interactivity occurs in the space and the relation it has to the sonic elements is an issue of importance and many times strategies are utilized to find the most interesting way to engage participation and attachment to the environment. Interactive systems try to present some sort of similarity between the information that is received from the outside world, and the automation of the design process that outputs an analogous function into another domain. However, the direct representation of specific information to distinct sound parameters can visualize the mapping more accurately, although it is also important to create a context for exploration and constant discovery. As Golan Levin has suggested (Levin, 2000) an interactive system needs to be 'instantly knowable and indefinitely masterable', so that it can involve the most active and interesting participation that can also 'motivate [the user] to search for the underlying rules of the game' (Jakovich et al., 2007). A sophisticated mapping process 'suggests a matrix of possibilities' that 'has the function of engaging the user' (Rebelo, 2003), and also has to present 'immediacy and intuitive understanding (comprehensibility) through its network of mapping' (Campo et al., 2004).

This study considers these issues as fundamental concepts for sound interaction and design, and tries to establish a framework where different strategies can be easily utilized for better engaging possibilities, constant exploration, and variability. In order for this to be realized, the information that is received from the environment needs to present 'knowledge about the ways in which flows and activities occur in architectural and social spaces' (Beilharz, 2005). By extracting socio-spatial information like motion, presence, and position, it is feasible to create events with intensity and dynamics that closely relate to sonification or compositional processes. Social behavior is an important aspect that can be measured, as it provides information about the activity, the number of people that have entered the space, and also create micro and macro scales of events. Furthermore, social threshold can be accounted as another occurrence for the quantification of the overall flow, minimum and maximum activity, or the spatial clustering of the environment. According to these issues a successful design process needs to relate context, measured data, system processing, and the responses from the inhabitants into a new sonic environment that is sensitive, functional, and creative.

Research Questionnaire

To complete the methodology process and to understand the average listener's relation to the subject of interactive sonic design into architectural spaces, a questionnaire has been developed. The information that was gathered was treated only as a guideline to the comprehension of where attention needs to be focused first, and furthermore finding strategies and solutions to problems that needed alternative approaches. The questionnaire and the results are presented in the appendix section of this thesis.

The total of 30 subjects participated to this research, from which 18 are male and 12 female, with an average age of 28. There were 7 people related to sound and music, 4 others to architecture, and 2 of them to sound and architecture. The rest are unrelated to the subject, and for this reason the questionnaire was in a simple and concise form, so that it can be an easy way to approach the subjects and learn about their preferences and opinions, but same time to extract meaningful information.

From the results it becomes apparent that subjects are open to new scenarios in the way architecture is experienced, and they prefer a case where more flexible applications are investigated. Most of the subjects want to feel comfortable with the spaces they occupy, although aesthetics and functionality are important for them too. However, it seems that the average participant does not prefer to have state-of-the-art equipment and advanced technology in the surrounding environment, except only if they are embedded in an easy and reconfigurable interface that supports needs and preferences, does not become obtrusive, and provides important services to its user. The aural awareness of the subjects seems to be quite high – although most of them do not have a priori knowledge on sonification, or aural semantics – and this level enables them to consciously be aware and critical about the sonic properties of the soundscape, which must be of a fine quality according to their opinion. Finally, it is observed, as mentioned already, that the subjectivity and diversity of opinions concerning sound preferences is most likely to create difficulties for the design process in order to reach an attractive and sensual result.

This concludes the issues that have been considered for the methodology of interactive sonic design into architectural spaces. Most of the information that has been already provided helped for the development of a software system that comprises part of the investigation of this thesis.

Chapter 4: System Development

> '*Recalibration of desire released in the attainment of new technical capacity*' (Goulthorpe, 2002).

Strategies

In the previous chapters the idiosyncratic and eccentric nature of the relationship between sound and architecture is presented, and it becomes clear that the design process has to incorporate a variety of aspects properly, if a meaningful result is to be delivered. Moreover, it needs to be acknowledged that the diversity of the needs each space has, and the subjectivity of their inhabitants makes the design process a difficult and complicated matter. For this reason, I have developed a framework that aims to provide solutions to these problems, and integrate aesthetic and technological approaches to the architectural space through flexible sonic design. This work intends to establish fundamental demands and necessities for expressing sonic information to the environment, and enable the discovery of strategies for easy and effective reconfiguration according to the context.

During the process of programming a system that is going to be used for the sound design of a particular space, I decided to make my intend more ambitious and create an interface that is flexible to be configured easily in any environment. The quality of the sound processing should not be minimized or affected, offering a number of modules to facilitate different needs. In addition, I chose the system to include interactive functions and to be compatible with other programs and computers, so that a greater network of utilities to provide the means for better design opportunities.

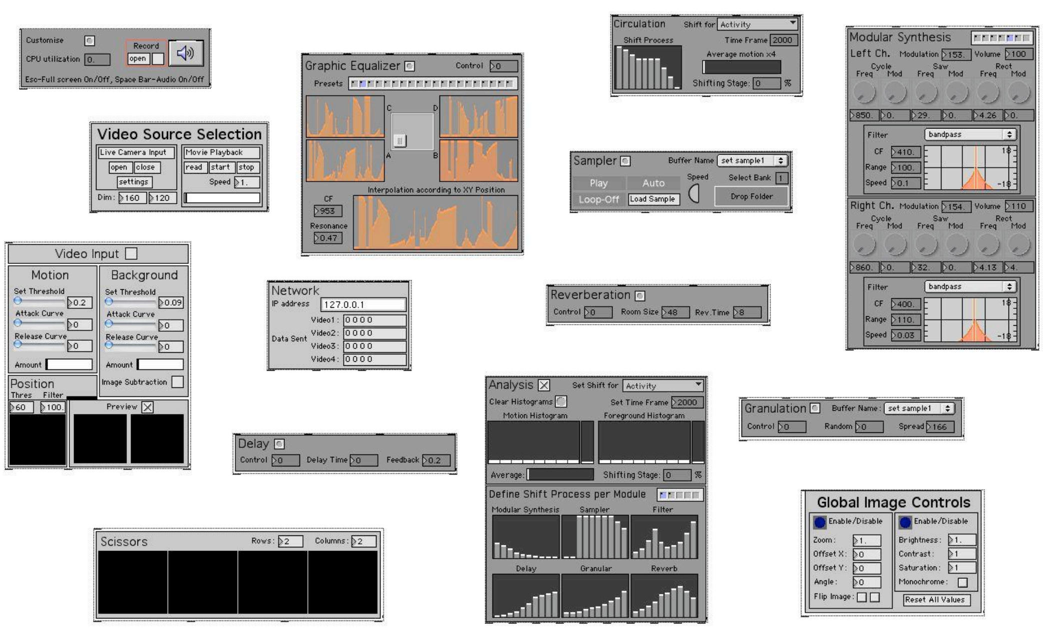


Figure 14 - Modules of the System

Because of this, I have developed a *Computer Vision Analysis* (*CVA*) system that configures and analyzes images from the architectural space, and distributes them over the network to the *Sonic Architect* a second system that is used for the analysis, mapping, and sonification of the received data. The programming infrastructure that has been followed for these systems is based on interconnected reconfigurable, changeable modules that can be utilized and implemented for custom sound design.

Max/MSP (Cycling '74, 2007) is used as the main programming environment for both systems. Due to the difficulty of interacting with Max/MSP's complex visual environment with hundred objects and cords, the necessity to define a user interface was apparent. Methods were developed to introduce the design of practical and effective interfaces. Each task is separated and classified as one coherent module that becomes a building block to the construction of custom interfaces. Except the configuration controls and the visual feedback of their current statuses, the modules have all their functions embedded under the surface. This gives the advantage to the user to alter the arrangement of the modules faster and a lot more effectively, and same time enable connectivity and compatibility to internal or external, mobile and dislocated programming units.

Computer Vision Analysis

The system can process information from external socio-spatial data with the operation of computer vision algorithms that have been developed with the use of *Max/MSP*, *Jitter* (Cycling '74, 2007) and the open source *cv.jit* library (Pelletier, 2006).

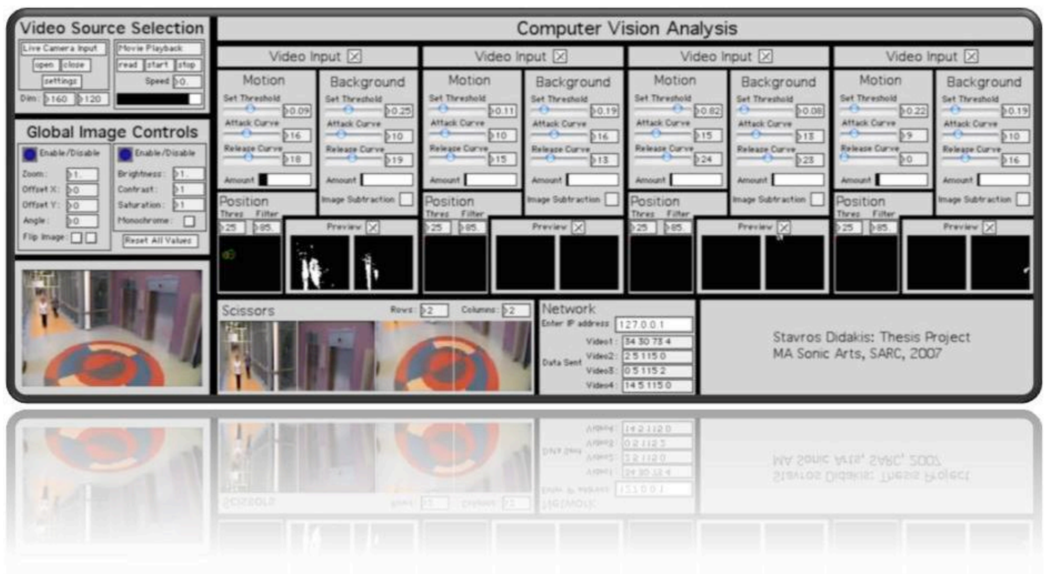


Figure 15 – Computer Vision Analysis (Screenshot)

The reason I have chosen computer vision and image analysis as the main sensory input, is because it is a technology straightforward, cheap, effective, and can be easily embedded into the architecture to provide a 'sensate space', that is, a 'social space in which the sensors are inherent and unobtrusive' (Campo et al., 2004). *CVA* supports a number of image controls for playback, resolution, spatial position and configuration, in a similar way the *Musical Gestures Toolbox* works, although *MGT* is focused mainly on the study of musical gestures (Jensenius et al., 2005).

This system on the other hand, utilizes modules for the analysis of socio-spatial information that includes motion, presence, and position tracking. The sensitivity of the analyzed information can be configured so that smooth responses can be accomplished. The importance of the system's modularity is apparent when separate locations of the architectural space need to be captured and analyzed, and the employment of multiple instances of the modules can provide the desired case. However, it is crucial to acknowledge the processing demands of image analysis, and although optimization techniques have been developed, a great number of analysis algorithms may require alternative ways to accomplish the task, such as to use two or more computers for processing. For this reason I have developed a data distribution network with the use of Open Sound Control (Wright et al., 2003) that enables an effective way to exchange information between programs or computers, in local or distant networks.

Data Analysis

Due to the mapping problems every interactive system has, and because of this framework's demand for flexible control, I have created solutions to the linking processes between the socio-spatial data and the control of the sound parameters. These processes do not constrain the user with predetermined connections that are fixed and permanent, but rather it offers a case to define custom data processes and distribution utilities for further configuration, analysis or sound control.

In this framework I try to observe the representation of the incoming socio-spatial information into less abstract and more meaningful ways, so that similarities of the actual phenomena to become valuable information for the control of sound design in real-time. The statistical processes that have been implemented into the system are able to extract information from the inhabitants and the spaces they occupy, and to create sonic elements according to the analyzed information. It is achievable to define the activity and the overall circulation of a space by averaging motion and presence values of the areas that seem to be mostly occupied. Moreover, the statistical processes are able to map a number of observations into disjoint categories (bins), and create histograms according to the incoming data. These histograms can define clusters of occurrence so that each environment can be further characterized as smooth and relaxing, or more aggressive and neurotic. Also, it is possible to observe and control the processes as a function of time with the use of timeline controls that have been implemented to generate shifting processes and transitions from a stage to the next. In each stage it is possible to set the control parameters of each sound module separately, and generate sonic events that closely match the data processes.

Custom configurations of the module interconnections determine which parameter is altered at each time so that the shifting process can be automated as a progressive function in space and time. This means that the system provides the opportunity to create a case where the parameters of the sound modules are shifted analogously to the socio-spatial activity. Any configuration can be adopted and saved for future reference if desired. Fluidity and constant change according to this process become tools that the designer can automate to control a preferred sonic environment.

The Sonic Architect

The analysis functions of the incoming information together with the sound modules that have been developed for this system have been implemented into the *Sonic Architect*. This program provides a number of interactive sound modules that can obtain preference and functionality in a variety of cases. The designer can easily map socio-spatial information such as motion, activity, presence, position, circulation and so on, for the control of the sound modules.

There are a number of sound design possibilities that range from real-time synthesis, to audio playback, and sound effects. First, I have created an interactive synthesis engine with a variety of oscillators and filters that provides a simple and efficient way for the creation of modulating sounds, and to their distribution in space if desired.

Any control parameter of the synthesizer can be connected to interactive elements; however, in this case each motion amount from the four cameras controls either an oscillator, or filter coefficient. Moreover, the circulation average of this activity controls the shifting process of the module that corresponds to its volume automation.

Next, there is a sampler module that may receive any number of audio tracks, and automatically load, configure, mix, and play back these files. Activity that is captured in space, either motion or presence, determines the volume of the sampler, which creates a sonic accompaniment even with still subjects. Other interactive functions can be set for more complicated matters, such as the selection of a sound list according to histogram activity, and with this feature it is possible to shift from a specific sonic environment to the other depending on the analyzed data. The overall circulation in this case determines if the sampler is included in the sonic reconstruction of the space or not. The output of the sampler is connected to the graphic equalizer that uses a 256-band filter and its shape is created in real-time according to the interpolation in XY coordinates between four user-defined tables. These table values may also change automatically after an amount of time so that constant variability is achieved. In this particular case the position of the tracked subjects control the way the interpolation alters the filter bands and the motion amount sets center frequency and resonance parameters. Dry and filtered signals are defined from the shifting process of the overall circulation.

Figure 16 – The Sonic Architect (Screenshot)

The output of the filter is connected to a delay module that can facilitate interactive parameters for delay mix, time and feedback. In this particular case the motion amount controls the delay time, and the shifting process defines its overall volume as well. Following, there is a granulation module that records 'micro acoustic events' (Roads, 2001) from any sampler the user defines, and manipulates interactively the randomization and spread amount of these snapshots across the audible frequency spectrum. Finally, the output of the granulation is connected to a reverberation module that can also be interactive according to the incoming information.

In this set-up the system receives information from four cameras and creates sonic events accordingly. However, this is only one version the system can accommodate, as it is possible to set custom configurations that utilize sound modules with a number of socio-spatial data functions, and furthermore realize dynamic design attributes such as the distribution of the sound signals in any desired part of the space.

Summary

The combination of the aforementioned systems that have been developed specifically for this work complete a fully operational framework, which can be used autonomously for the sound design and programming in architectural spaces. The system affords the option to devise a sonification process that defines directly the physical space and vice versa. It is up to the user to specify in which level the socio-spatial data control the soundscape, the degree of interactivity, how often shifting processes happen, what is the relation between the sound modules, the rhythm of the events, and also how sound is distributed back into space. Moreover, the infrastructure of the system enables new functional and creative ways for the foremost control parameters, leaving the rest functions for discovery by 'the occasional, more sensitive visitor' (Franinovic et al., 2007), creating an interesting interactive context in a space of architecture. Socio-spatial data then become easily manipulated and the parameters of the sound modules can be controlled in time and space.

The following chapter presents a practical application of this proposal into a public space installation. Sound design strategies are analyzed and evaluated.

Chapter 5: Case Study – Royal Victoria Hospital

A case study for the system of this thesis was developed as a public space installation in Royal Victoria Hospital in Belfast, one of the biggest and well-known hospitals in Northern Ireland. The system is installed into the main hallway that plays the role of a physical navigational interface, providing access into clinics, wards, and also connections via lifts to other levels of the building.

Previous Work

A previous installation exists in the space, originally developed to '[enrich] hospital users' experiences through the arts' (Rebelo et al, 2005). The installation uses motion sensing of general levels of activity, and according to the time of the day 'specific number of patches that ‘contain isolated sound works with individual interaction and spatialization strategies’, ‘are candidates to be loaded into the system’ (Rebelo et al, 2005). The environment is semi-generative and the sonic worlds contain mostly environmental and instrumental pieces. There are transitions of silence between each piece, and these ‘silent transitions’, ‘are as important as the sound worlds themselves’ (Rebelo et al, 2005).

Design Methodology

This installation on the other hand uses a slightly different approach. The articulation of the sonic elements is directly related on the socio-spatial information that is extracted from the participants on the hallway. Shifting events take place in time and space, and the system’s fluidity depends on the occupants’ interaction. The system proposes functions and ideas that may be ‘familiar’, ‘engaging’, and ‘immersive’ (Bandt, 2002), and zoning techniques have been devised to enhance the spatial dimensions of the architectural space. The system uses 4 cameras as the sensory mechanism, and 16 channels to distribute the sound in space, and the sonic articulation provides a case that fluctuates ‘between art, function, real and virtual’ (Crow & Prior, 2004).

The spatialization of the hallway was problematic as there are no centre positions for the listeners, and a 'multiplicity of the listening perspectives' (Giomi et al., 2003) was an important design criterion. For this reason, global and local design techniques have been constructed, so that aspects of the sonification are experienced as rhythm events, and it is up to the listener to explore the relationship between sound and space.

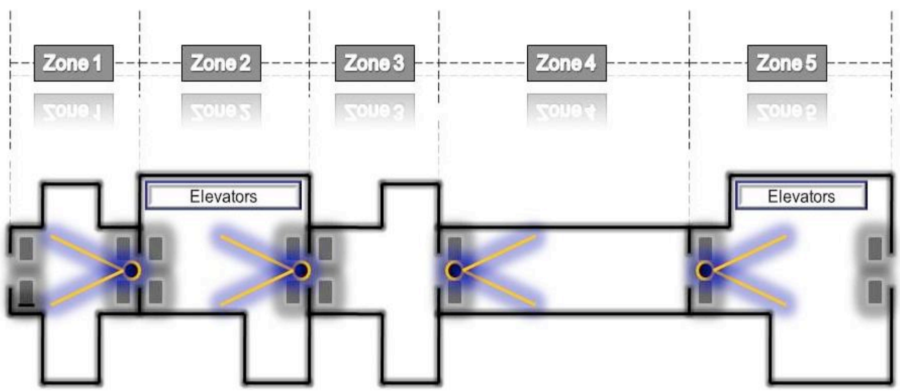


Figure 17 – Hallway of Installation

A main consideration was to create a soundscape that enables the participants to apprehend the architectural space aurally, provide engaging interactive features, and create a sonic context that evokes memories, passions, and emotions. Representing information with sound elements can serve as a way to 'elucidate patterns, behavioral trends, cliques, recurrences' (Beilharz, 2005), and furthermore it can reveal temporal and chronological structures that characterize the nature and purpose of this environment. Other considerations deal with the matter of intensity and sensitivity so that the sonic feature does not become a 'source of distraction or annoyance'

(Birchfield et al., 2006). Social and artistic dynamics have both been encountered for the design of the sound, and the visitors can participate in an artistic experience that enhances their aural awareness and re-contextualizes them, as also the space itself.

Modular synthesis is programmed to behave in a number of ways. First, the motion interaction from the four cameras is averaged and the amount controls the shifting process of its synthesis and spatialization. Minimum interaction spatializes the sound in the 16 speakers iteratively in a spiral simulation representing the DNA formation. The sound moves from one speaker to the other iteratively and then back and forth across the distance of the hallway with a speed that depends on the average motion level that is measured across the hallway (usually it varies from 3 to 5 seconds for a complete movement).

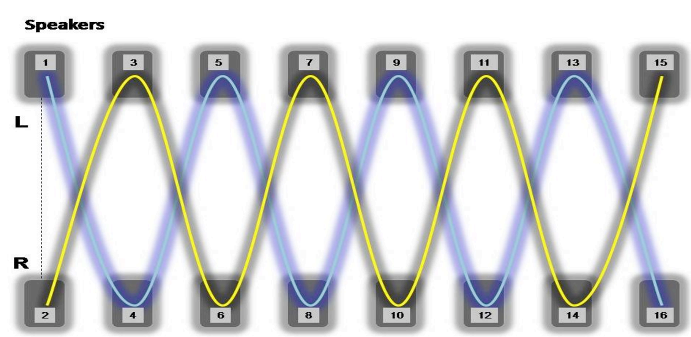


Figure 18 – Spatial Formation

The synthetic sounds are low frequencies that are slightly detuned from left and right output in the same way binaural beats occur. The frequency difference of the two outputs is at 10 Hz, representing the Alpha state, which is known to provide a state of relaxed consciousness, and it results in 'stress reduction, pain control, and the improvement of concentration and information retention' (First, 2003).

Motion amount that is tracked from each camera controls a specific parameter of the synthesis, such as filtering and resonance, and the collaboration of these interactive data define the sound result. Moreover, shifting processes in the synthesis and spatialization parameters occur according to the statistical analysis of the circulation as events in a period of time. If a social threshold is passed, the spiral formation of the sound across the hallway fades away, and the modular synthesis can be heard only in each isolated zone if local motion is detected. The growing patterns of motion and circulation activity shift the parameters of the synthesizer, and each time the sound behaves analogously to these values. Consequently this sonification process becomes an agent for creating aural awareness, linking metaphorically to the medical world, and furthermore providing aural information for relaxation or even meditative states.

Three units of modules create the rest of the sonification process, and each one is responsible for zones 2, 4 and 5 of the hallway accordingly; zone 1 is used as an introductory zone having only binaural elements, and zone 3 is considered as a space of silence and anticipation. Each unit uses a sampler, a graphic equalizer, a delay, a granulator, and a reverb module. The sampler unit has different sound banks with audio files ranging from environmental (i.e. sea wash, birds, and trees in the wind) to more social and industrial sounds (playground, festival, breeding machine, etc), and their variance and diversity proposes a way to evoke different memory locations and emotions to the participants. The sounds have been selected, edited, and modified specifically for this installation, and there are more than 350 audio files in each sampler module that are selected automatically, as a function has been programmed to control which bank is loaded each time depending on the local circulation. More social activity defines sounds with more complex and noisy spectra, although sometimes they may be more interesting as well. Subjects' position is used as coordinate information that controls the interpolation of the graphic equalizer. The preset configurations change every few minutes so that new interesting sound colors can be introduced. The granulation of the sound file is defined by social activity over a period of time, and sample randomization and spread are also controlled from the interaction. Delay and reverberation modules are interactive as well, and they mostly depend on motion activity in the local space.

Results

The installation follows a generative sound approach that intents to attract interest and engagement through attentive listening. However, the aesthetics of the work are considered only in 'its broadest manifestations', as similarly 'music can be roughly considered to be sounds made with aesthetic intent, or even sounds listened to with aesthetic interest' (Garnett, 2001). The design provides the aural means for the visitors to experience relaxing and atmospheric sounds that may enhance their experience inside this space and motivate them to explore this sonic beautification of the environment.

System's behavior becomes a way to employ metaphors to the sonification process according to the spatial visits and occurrences. The overall circulation affects the processing algorithms that are responsible for the alteration of the original sound material in such a say that the noisy and complicated environment of the urban setting is reflected. If the circulation reaches specific threshold values, equivalent behavior is created. Same time, the system intends to respect discreetness and not to violate the functionality and purpose of the hallway.

Another consideration is that an interactive sound system in a public space needs to acknowledge the full range of audience so that it can present a 'multilayered work that will be engaging on many cognitive, physical and emotional levels' (Winkler, 2000), yet, it is rather impossible to achieve such an ambition in the present work, as the occupants vary from staff, visitors, and patients of variable age and culture.

One problem that occurs in this installation, and in many other similar sites, is that space becomes a significant factor to the apprehension of the work, as it is impossible to 'be perceived simultaneously' (Coburn, 2002). This is a general problem though, as the correlation between sound design and architectural space needs the accumulation of the work through physical interaction and movement so that the dimensions of the work to be expanded.

The processes of this installation system are analogous to the way participation occurs, and the articulation of the sonic environment depends on a variety of parameters, such as interactive participation and controlling functions that ensure certain shifting processes occur at specific events. Referential sounds that have been used intend to create an environment of collision and evoke memories, awareness, and consciousness. Furthermore, sonic actions are considered both locally and globally, and the system behaves as a coherent organism with 'feelings, moods, oddities and idiosyncrasies' (Didakis, 2007).

Chapter 6: Conclusions

Discussion

A main consideration of this thesis is to find ways to use sound as a catalyst for the transformation of an environment's perceptual qualities into positive and engaging features. However, it is rather difficult to evaluate sound material that tries to achieve such an ambition, due to the reason that no semantics have been developed to determine cognitive processes of individuals. Sound selection and design methods that are followed in this work are based on preceding studies on this subject that include semantic, cognitive, spatial, aesthetic, psycho-physiological, and technological areas. Thus, it was important to consider these interdisciplinary approaches, and create a framework that encapsulates a variety of functions in order to construct a tool for sound design exploration. Proper study of the soundscape together with a creative design philosophy is possible to create engaging sonic atmospheres that the inhabitants prefer and enjoy. The use of the proposed system and its sound library may provide an autonomous function that can be tuned accordingly to the attainment of specific ambiences into spaces of architecture.

The *Computer Vision Analysis* and the *Sonic Architect* systems are only a demonstration of the possibilities the programmed modules may offer, as their modular architecture enables the flexibility to construct custom analysis and processing functions according to the user needs. This modular approach however, does not compromise sound quality or processing speed, but instead provides advantages and easy access to utilities for sound design configurations. It is difficult to describe the sonic attributes and processes of the system as sound art, composition, or radio music per se, but rather its purpose intends to become a vehicle for conveying positive and relaxing atmospheres to the subjects, in such a way that the perception of the environment may be enhanced. According to the ways these spaces are experienced, information is extrapolated that is used for the automatic configuration of their sonic environments. Thus, the system may be categorized into architectural interactive sonic design, a term that characteristically describes this thesis as well.

The public installation in Royal Victoria Hospital tries to incorporate all the previous studies and methods that have been discussed, such as approaches to soundscape design, sound material selection, and the way socio-spatial information can be analyzed and mapped to the sound environment. Spatialization techniques that are followed, draw attributes from sound art installations, and also from composition approaches. The sonic occurrences in the space define a score for relations of the sound distribution and spatialization. These design techniques try to extend the notion of the aural space, and use the sound material as a way to enhance the experience and increase the perception of the environment, as in the case of *Cylindre Sonore* for example.

Future Directions

Further developments of the system may include the construction of a greater range of sound modules, or even provide VST plug-in support and compatibility, as also Rewire technology, so that any commercial audio software to be inherited easily into the system. This case would give the benefit to implement external sound modules of preference and use them in combination with analysis techniques in real-time.

Although the system has been already applied into a public installation, it would be even more useful to test it in various contexts from public spaces, to sound art installations, and to more personal environments. Between these diverse settings the system's power should be evaluated properly, and the results would direct updates for a more efficient and universal approach.

Other ideas for future work include the systematic observation of the socio-spatial clusters in various cases, so that social occurrences can be formed into more scientific and less abstract relations, and furthermore, study how these results can be mapped to the parameters of sound. The clusters of information can also create a context for interactive generative visualization of the processed information for communicative, informative, or aesthetical purposes. This would also project real and virtual fusions that may be used for the design of a space according to social or personal preferences.

Finally, the combination of various sensors could be employed to extract further information about the space and its occupants, for example receive 3D information, measure anxiety levels, or even retrieve emotional states. The integration of various technologies and their cross-reference may provide a case where the participants actually control many aspects of the environment they inhabit, giving them the gift of freedom and possibility.

Conclusion

In this work I have attempted to define the relation between sound design, interactivity, and architectural spaces from a number of different perspectives. I have discussed about the association of sound and space, and how they can configure each other according to the physical or poetical attributes they convey. This transformation has enough power to affect mood, behavior and perception of the person that occupies the space. For this reason it is possible to apply practices that determine better flow of energy in a space, as in the case of Feng Shui, or redefine the aural identity of a space with the use of sonic design in order to create more supportive and personalized environments. I have presented information concerning the study of the acoustic environment and methods that can be utilized in order to improve its sonic qualities. Methodologies and strategies for soundscape design are presented, as also studies concerning sound material selection for specific moods.

The system that has been developed for this work, intends to become a framework for the construction of sonic elements according to the analysis of incoming socio-spatial information, and moreover to enable the discovery of mapping strategies for specific configuration in each context. Custom interfaces can be utilized as the system follows a modular approach, and its efficiency and flexibility enables the realization of new sound design possibilities. As spatial information and social behavior are key factors to interactive sonification of architectural spaces, computer vision techniques have been implemented in order to enable feature extraction from custom areas of the environment. Statistical processes define relations of the incoming information such as patterns of occurrence, activity, circulation, and clustering of the space, and these processes are used to control parameters of the interactive sound modules. It is possible to explore the incoming data and discover mapping methods to the sonification process according to the context and the needs of the space, transforming the perception and the experience of the environment accordingly.

In conclusion, this work intends to expand the notion of sound design and to use the potential of digital technology for integration inside the building fabric of the physical spaces we occupy, define areas of interference and use the architecture as a sonic vehicle or instrument. According to this, inhabitants of the environment would have the opportunity to enjoy relaxing ambiences in a more interactive way, and to create a vocabulary of sound design that is applied to the accompaniment of our daily lives. This case would create an expressive form of living architecture that uses sound as a medium to create pleasant moods, give richness and texture to the space, and furthermore create links and connections to an enhanced version of inhabitancy; a case where our senses receive only the finest information that open connections to the mystical energies of the universe.

Bibliography

Adorno, T. 1997, ‘Functionalism Today’, in *Rethinking Architecture*, ed. N. Leach, Routledge, London, p.10.

Anderson, L. M., Goodman, L. S., Mulligan, B. E. & Regen, H. Z. 1983, ‘Effects on Sounds on Preferences for Outdoor Settings’, *Environment and Behavior*, vol. 15, no. 5, pp. 539-566.

Bachelard, G. 1994, *The Poetics of Space*, Beacon Press, Boston.

Barker, R. G. 1968, *Ecological Psychology*, Stanford University Press, Stanford, CA.

Bandt, R. 2002, ‘Spatial Counterpoint as a Design Principle in the Australia Gallery, the Melbourne Museum’, *Proceedings of the Australian Computer Music Conference*, Melbourne, pp. 7-16.

Baudrillard, J. 1983, *Simulations*, trans. P. Foss, P. Patton, P. Beitchman, Semiotext(e), New York.

Beilharz, K. 2005, 'Gesture-Controlled Interaction with Aesthetic Information Sonification', *Proceedings of the Second Australian Conference on Interactive Entertainment,* ed. Y. Pisan, vol. 123, pp. 11-18.

Birchfield, D., Phillips, K., Kidane, A. & Lorig, A. 2006 'Interactive Sound Art: a Case Study', *Proceedings of the 2006 International Conference on Mew Musical Interfaces for Musical Expression* (NIME06), Paris, pp. 43-48.

Blesser, B. & Salter, L. R. 2007, *Spaces Speak, Are you Listening? Experiencing Aural Architecture*, MIT Press, Cambridge, Massachusetts.

Bronzaft, A.L., Ahern, K. D., McGinn, R., O'Connor, J., & Savino, B. 1998, 'Aircraft Noise: A Potential Health Hazard', *Environment and Behavior*, vol. 30, no. 1, pp. 101-113.

Brown, A. L. 2003, 'Acoustic Objectives for Designed or Managed Soundscapes', *Soundscape: Journal of Acoustic Ecology*, vol. 4, no. 2, pp. 19-23.

Bullivant, L. 2005 'Ada: the Intelligent Room', in *4D-Space: Interactive Architecture*, ed. L. Bullivant, Wiley-Academy, West Sussex, p. 86-89.

Cage, J. 1961, *Silence: Lectures and Writings by John Cage*, University Press of New England/Wesleyan University Press, Hanover, NH.

Campo, A. D., Frauenberger, C. & Holdrich, R. 2004, 'Designing a Generalized Sonification Environment', *International Conference on Auditory Display (ICAD)*, Sydney.

Carles, J., Bernaldez, F. & de Lucio, J. 1999, 'Sound Influence on Landscape Values', *Landscape and Urban Planning*, vol. 43, no. 4, pp. 191-200.

Classen, C. 1993, *Worlds of Sense: Exploring the Senses in History and Across Cultures*, Routledge, New York.

Crow, F. & Prior, D. 2004, 'Swash: A Case Study', *Earshot*, vol. 4, pp. 17-21.

Coburn, R. 2002, 'Composing Space: The Integration of Music, Time, and Space in Multi-Dimensional Sound Installations', *Proceedings of the Australasian Computer Music Conference*, Melbourne, pp. 143-148.

Copeland, D. 2000, 'Associative Listening', *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 1, pp.23-25.

Cycling '74, 2007, 'Cycling74 Webpage', Available at: http://www.cycling74.com

Delage, B. 2002, 'Sound in Architecture', *Earshot*, vol. 3, pp. 10-11.

Delbrück, T., Eng, K., Bäbler, A., Bernardet, U., Blanchard, M., Briska, A., Costa, M., Douglas, R., Hepp, K., Klein, D., Manzolli, J., Mintz, M., Roth, F., Rutishauser, U., Wassermann, K., Wittmann, A., Whatley, A. M., Wyss R., & Verschure, P.F.M.J. 2003, 'Ada: a Playful Interactive Space', *Interact 2003, Ninth IFIP TC13 International Conference on Human-Computer Interaction INTERACT'03*, Sept 1-5, Zurich, Switzerland, pp. 989-992.

Didakis, S. 2007, 'The Cube: An Audiovisual Interactive Installation', *Proceedings of the 4th Sound and Music Computing Conference (SMC'07)*, eds. C. Spyridis, A. Georgaki, G. Kouroupetoglou & C. Anagnostopoulou, Lefkada, pp. 64-67.

Dorsey, T. 2002, ‘Revealing the continuum: an Investigation of Sound and Space’, *Earshot*, vol. 3, pp.12-15.

Elff, J. 2004 ‘Sounds in Space’, *Earshot*, vol. 4, pp. 49-51.

Eng, K., Baebler, A., Bernadet, U., Blanchard, M., Briska, A., Conradt, J., Costa, M., Delbruck, T., Douglas, R., Hepp, K., Klein, D., Manzolli, J., Mintz, M., Netter, T., Roth, F., Rutishauser, U., Wassermann, K., Whatley, A., Wittmann, A., Wyss, R., and Verschure, P. 2002, ‘Ada: Constructing a Synthetic Organism’, *Proceedings of the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Lausanne, Switzerland.

Eno, B. 1978, *Music for Airports*, Editions Eg Records, UK.

Eno, B. 1996, *A Year with Swollen Appendices*, Faber & Faber, London.

Fontana, B. 1996, ‘*Borrowed Soundscapes: the Sound Sculptures of Bill Fontana (1973-1996)*’, Available at: http://www.resoundings.org

Franinovic, K. & Visell, Y. 2007, ‘New Musical Interfaces in Context: Sonic Interaction Design in the Urban Setting’, *Proceedings of the 2007 Conference on New Interfaces for Musical Expression* (NIME07), New York, pp. 191-196.

Franklin, U. 2000, ‘Silence and the Notion of the Commons’, *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 2, pp.14-17.

First, D. 2003, ‘The Music of the Sphere: An Investigation into Asymptotic Harmonics, Brainwave Entertainment and the Earth as a Giant Bell’, *Leonardo Music Journal*, vol. 13, pp. 31-37.

Frykberg, S. 1999, ‘Acoustic Dimension of Communication 1’, Communication 259 Study Guide, SFU, Burnaby, B.C. Canada.

Gallagher, W. 1994, *The Power of Place: How our Surroundings Shape our Thoughts, Emotions, and Actions*, Harper Perennial, New York.

Garnett, G. E. 2001, ‘The Aesthetics of Interactive Computer Music’, *Computer Music Journal*, vol. 25, no. 1, pp. 21-33.

Giomi, F., Meacci, D. & Schwoon, K. 2003, ‘Electro acoustic Music in a Multi-Perspective Architectural Context: a Sound Installation for Renzo Piano’s Auditorium in Rome’, *Organized Sound*, vol. 8, no. 2, pp. 157-162

Goulthorpe, M. 2002, ‘Smectic State’, in *Designing for a Digital World*, ed. N. Leach, Wiley Academy, West Sussex, pp. 101-107.

Hedfors, P. 2003, *Site Soundscapes: Landscape Architecture in the Light of Sound*, PhD Thesis, Department of Landscape Planning Ultuna, Uppsala.

Heisenberg, W. K. 1958, *Physics and Philosophy*, Harper & Brothers, New York.

Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B., & Yarin, P. 1998, ‘ambientROOM: Integrating Ambient Media with Architectural Space’, *Conference Summary of CHI ’98*, Atlanta, GA, pp. 1-2.

Jasnoski, M. B. 1991 'Architectural and Interior Features Affect Mood and Cognitive Performance', *Journal of Applied Developmental Psychology*, vol. 131, pp. 117-124.

Jakovich, J. & Beilharz, K. 2007, 'ParticleTecture: Interactive Granular Soundspaces for Architectural Design', *Proceedings of the 2007 Conference on New Interfaces for Musical Expression* (NIME07), New York, pp. 185-190.

Jensenius, A. R., Godoy, R. I. & Wanderley M. M. 2005, 'Developing Tools for Studying Musical Gestures within the Max/MSP/Jitter Environment', *Proceedings of the International Computer Music Conference*, Barcelona, pp. 282-285.

Jones, S. 2006, 'space-dis-place: How Sound and Interactivity Can Reconfigure Our Apprehension of Space', *Leonardo Music Journal*, vol. 16, pp. 20-27.

Karlsson, H. 2000, 'The Acoustic Environment as a Public Domain', *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 2, pp. 10-13.

LaBarbara, J. 1977 'Max Neuhaus: New Sounds in Natural Settings', *Musical America*, October.

LaBelle, B. 2002, 'Causing effects: Between Sound and its Source', *Earshot*, vol. 3, pp. 8-9.

Leach, N. 2002, 'Forget Heidegger', in *Designing for a Digital World*, ed. N. Leach, Wiley Academy, West Sussex.

Levin, G. 2000, *Painterly Interfaces for Audiovisual Performance*, MSc Thesis, School of Architecture and Planning, MIT, Massachusetts.

Lucier, A. 1990, ‘I am Sitting in a Room (1970), for voice and electromagnetic tape’, in *I am Sitting in a Room*, A. Lucier, Lovely Music, Ltd, New York.

MacKinnon, D. 1963, ‘Creativity and the Images of Self’, in *The Study of Lives: Essays of Personality in Honor of Henry A. Murray*, ed. R. White, Atherton Press, New York.

Martin, E. 1994, *Architecture as a Translation of Music*, Princeton Architectural Press, New York.

Miller, W. 2000, ‘Silence in Contemporary Soundscape’, *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 2, pp.18-13.

Moser, G. 1988, ‘Urban Stress and Helping Behavior – Effects of Environmental Overload and Noise on Behavior’, *Journal of Environmental Psychology*, no.8, pp. 287-298.

Neuhaus, M. 1994, *Sound Works: Volume I – Inscription*, Cantz, Ostfildern-Stuttgart.

Neuhaus, M. 1995, *Evocare L'Udibile*, Charta, Milan.

NOX (2004), ‘*Son-O-House'*, Available at:
http://www.evdh.net/sonohouse/nox.html

Pager, V. 1932, *Music and its Lovers: An Empirical Study of Emotions and Imaginative Responses to Music*, Allen and Unwin, London.

Passchier-Vermeer, W. & Passchier, W. F. 2000, ‘Noise Exposure and Public Health’, *Environmental Health Perspectives*, vol. 108, pp.123-131.

Pelletier, J. M. 2006, '*cv.jit – Computer Vision for Jitter'*, Collection of objects. Available at: http://www.iamas.ac.jp/~jovan02/cv/

Princeton, 2004, *Tapestrea: A new way to Design Sound*, Available at http://taps.cs.princeton.edu/

Puglisi, L. P. 1999, *Hyper Architecture: Spaces in the Electronic Age*, Birkhauser, Basel, Switzerland.

Rasmussen, S. E. 1959, *Experiencing Architecture*, MIT Press, Cambridge, Massachusetts.

Rebelo, P. 2003, 'Performing Space', *Organized Sound*, vol. 8, no.2, pp. 181-186.

Rebelo, P., Alcorn, M. & Wilson P. 2005, 'A Stethoscope for Imaginary Sound. Interactive Sound in a Health Care Environment', *Proceedings of the International Computer Music Conference (ICMC'05)*, Barcelona, pp. 829-832.

Reed, V. 2000, 'Living Out Loud', *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 2, pp.22-23.

Roads, C. 2001, *Microsound*, MIT Press, Massachusetts.

Rossbach, S. 1987, *Interior Design with Feng Shui*, E. P. Dutton, New York.

Rossbach, S. 1983, *Feng Shui*, E. P. Dutton, New York.

Rudi, J. 2005, ‘‘From a Musical Point of View, the World is Musical at any Given Moment’: an Interview with Bill Fontana’, *Organized Sound*, vol. 10, no.2, pp. 97-101.

Rushkoff, D. 2002, ‘The Digital Renaissance’, in *Designing for a Digital World*, ed. N. Leach, Wiley Academy, West Sussex, p. 16-20.

Schaefer, M. R. 1994, *Our Sonic Environment and the Soundscape – the Tuning of the World*, Destiny Books, Rochester, Vermont, 1994.

Scott, R. 2004 ‘Surface Architecture’, in *Earshot* vol. 4, pp. 13-16.

Slapper, G. 1996. ‘Let’s try to keep the peace’, in *The Times,* April 9th.

Steinberg, 2007, *Nuendo: Media Production System*, Available at http://steinberg.net/89_1.html

Suedfeld P. 1980, *Restricted Environmental Stimulation*, Wiley, New York.

Tak, W. 1958, ‘The ‘Electronic Poem’, performed in the Phillips Pavilion at the 1958 Brussels World Fair: The Sound Effects’, *Phillips Pavilion Technical Review*, no. 20, pp. 43-44.

Tamura, A. 2002, ‘Recognition of Sounds in Residential Environments: An Indicator of our Ambiguous Sound Environments’, *Journal of Architecture and Building Science*, vol. 117, no. 1496, pp. 41-48.

Terman, M. A. 1988, 'On the Question of Mechanism in Phototherapy for Seasonal Affective Disorder: Consideration of Clinical Efficacy and Epidemiology', *Journal of Biological Rhythms*, vol. 3, no. 2, 155-172.

Thompson, E. 2004, Wiring the World: Acoustical Engineers and the Empire of Sound in the Motion Picture Industry, 1927-1930, in *Hearing Cultures. Essays on Sound, Listening and Modernity*, Veit Erlmann (ed.), Berg Publishers

Truax, B. [Ed.], 1978, *Handbook of Acoustic Ecology*, A.R.C. Publications, Vancouver.

Truax, B. 2001. *Acoustic Communication*, Ablex Publishing, London.

U&I Software, 2006, *Metasynth: Sound Design Commercial Software*, Available at http://uisoftware.com/Metasynth/

van der Heide, Edwin (2004), '*The Composition of the Sound Environment for the Son-O-House*', Available at: http://www.evdh.net/sonohouse/evdh.html

Varese, E. 2004, 'The Liberation of Sound', in *Audio Culture. Readings in Modern Music*, eds. C. Cox & D. Warner, The Continuum International Publishing Group, New York, p. 17-21.

Vitruvius, 1960, *The Ten books of Architecture*, trans. Morris Hick Morgan, New York.

Wassermann, K. C., Manzolli, J., Eng, K. & Verschure, P. F. M. J. 2003, 'Live Soundscape Composition based on Synthetic Emotions', *IEEE Multimedia*, vol. 10, pp. 82-90.

Westerkamp, H. 2000, ‘Editorial’, *Soundscape: Journal of Acoustic Ecology*, vol. 1, no. 1, pp.3-4.

WHO, 2007, *World Health Organization*, Available at http://www.ho.int

Winkler, T. 2000, ‘Audience Participation and Response in Movement-Sensing Installations’, *Proceedings of the 2000 International Computer Music Conference*, Presented at the 2000 International Symposium on Electronic Art (ISEA), Paris.

Wishart, T. 1996, *On Sonic Art*, Harwood Academic, Amsterdam.

Wright, M., Freed, A. & Momeni, A. 2003, ‘Open Sound Control: State of the Art 2003’, *Proceedings of the 2003 Conference on New Interfaces for Music Expression*, Montreal, pp. 153-159.

Images

Ada [Image] 2007, Retrieved August 4th 2007, from http://ada.ini.ethz.ch/

Aegis, [Image] 2006, Retrieved July 20th 2007, from http://www.mediaarchitecture.org/wp-content/uploads/2006/06/PR_2003_hyposurface_002_p.jpg

Alvin Lucier [Image] 2007, Retrieved July 5th 2007, from http://a.parsons.edu/~mateo/thesis/plates/fAlvin.jpg

ambientROOM [Image] 1998, Retrieved August 3rd 2007, from Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B., & Yarin, P. 1998, 'ambientROOM: Integrating Ambient Media with Architectural Space', Conference Summary of CHI '98, Atlanta, GA, pp. 1-2.

Anechoic Chamber [Image] 2007, Retrieved July 22nd 2007, from http://acoustics.aau.dk/facilities/fac/anechoic-room-2/anechoic-room-2.jpg

Cylindre Sonore [Image] 2007, Retrieved July 18th 2007, from http://www.linternaute.com/imprimer/sortir/sorties/nature/jardins-villette/diaporama/images/5.jpg

First Telephone [Image] 2007, Retrieved July 5th 2007, from http://www.twu-local32.ca/pics/First%20telephone.gif

Gramophone [Image] 2007, Retrieved July 5th 2007, from http://history.sandiego.edu/GEN/recording/images4/12040107va.jpg

Human Mind [Image] 2007, Retrieved August 5th 2007, from http://psy.uq.edu.au/temp18/images/news/Psychology4a.jpg

La Guardia Airport [Image] 2007, Retrieved July 12th 2007, from http://medienkunstnetz.de/assets/img/data/3503/bild.jpg

MODAA [Image] 2007, Retrieved August 3rd 2007, from http://www.spfanews.com/ARTICLES/MODAA/modaa_corner_BUILDING.jpg

NOX [Image] 2007, Retrieved August 3rd 2007, from http://www.architecture.it/it/eventi/allegati/NOXSonO_2587.jpg

Philips Pavilion [Image] 2005, Retrieved July 12th 2007, from http://at.or.at/hans/misc/itp/newmediahistory/philipspavilion/pp4.gif

Surface Architects [Image] 2006, Retrieved July 20th 2007, from http://www.surfacearchitects.com/gfx/400amb08_copy.jpg

Varese [Image] 2007, Retrieved July 12th 2007, from http://www.furious.com/Perfect/ohm/graphics/varese.jpg

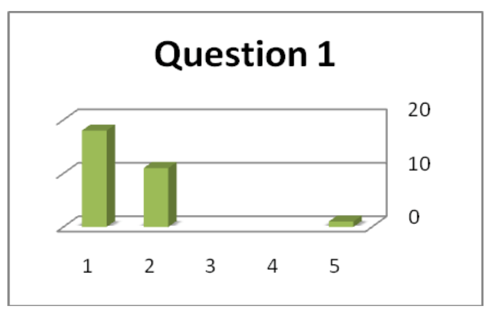
Appendices

Appendix A

Research Questionnaire and Results

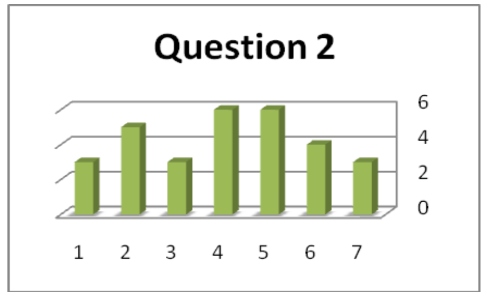
1) Do you believe that architectural design should incorporate sound and music, so that spaces can also be experienced aurally/sonically?

A. Strongly Agree
B. Agree
C. Disagree
D. Strongly Disagree
E. I don’t know



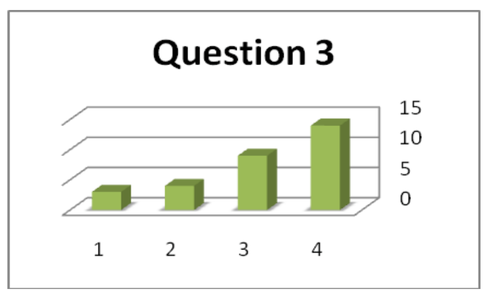
2) Imagine that you cross a hallway in a hospital. An interactive sound system is installed and specific groups of sounds that follow your movement through this space are triggered and played back. Choose from the following list below the one that you find most appropriate for the given space.

A. Sounds from a hospital environment (i.e. heart beat, equipment noise, etc)
B. Sounds from nature (i.e. seashore, rain, wind, etc)
C. Sounds from animals/birds/insects
D. Sounds from human activities (i.e. social gatherings, laughter, football game, etc)
E. Gentle musical instrumental sounds (bells, violins, etc)
F. All of the above
G. None of the above (Personal Preference)



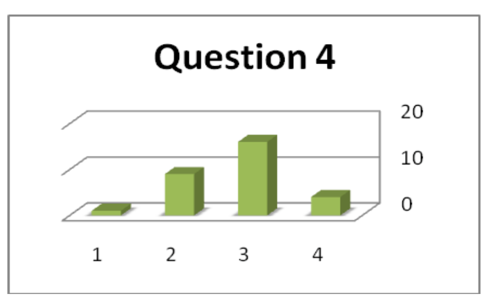
3) Whilst inside an architectural space (building, room, hallway, etc), are there times that you feel that the acoustic characteristics of the space create an awkward feeling (i.e. elevator silence, or noise in a shopping centre)? Do you feel that proper sound/aural control should take place to adjust the acoustic qualities and thus enhance the inhabitancy in this space?

A. I have never noticed anything like this before
B. I have noticed this before, but I don't mind
C. I have noticed this and it was a little disturbing
D. I have noticed this and I believe that proper control must take place
E.



4) In this space would you like to listen to the same motif (or sonic environment) every time you visit it, or to change over a period of time?

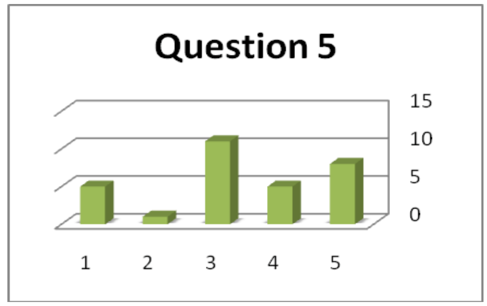
A. I want the same motif
B. Yes, I want it to change every few minutes
C. Yes, I want it to change every time I pass from this area



D. Yes, I want it to change once a month

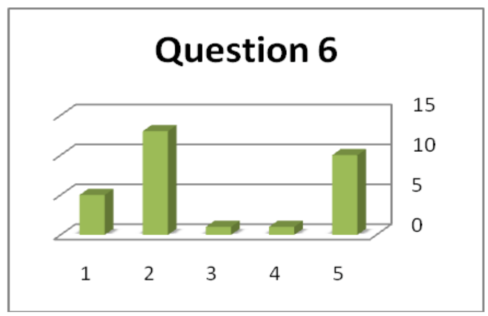
5) What do you believe is the best way to interact with this audio environment?

A. Press buttons on a remote device
B. Rotate or tilt a remote device
C. Use body movement or gesture
D. Voice recognition
E. All of the above, but distributed to different parts of the space



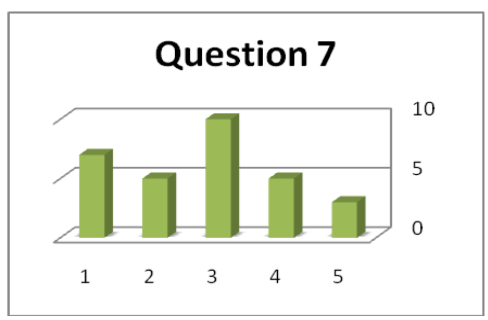
6) Imagine in that space that there is a plasma screen embedded in a wall. What do you believe that screen should display?

A. Abstract 3D visuals
B. Photographic images
C. Information (news, weather, stock market, etc)
D. Poems
E. All of the above



7) Which of the following you find most important for the design of such a space?

A. Aesthetics
B. Functionality
C. Comfort
D. Gadgets / Technology
E. Cost



Appendix B

Subjects and Answers

<u>Subjects</u>	**Quest. 1**	**Quest. 2**	**Quest. 3**	**Quest. 4**	**Quest. 5**	**Quest. 6**	**Quest. 7**
Ioanna	A	F	D	C	C	B	A
Kalia	A	D	C	D	D	E	E
Vaggelio	A	D	D	B	D	B	A
Stavros	A	D	D	C	E	E	C
Maria	A	E	C	C	C	E	C
Kostaki	A	A	A	B	D	A	D
Myros	B	B	C	A	A	C	E
Dimitris	A	C	D	D	E	B	B
Dad	E	C	B	D	D	B	E
Kostas	A	A	D	C	C	E	D
Katia	A	E	C	C	B	B	C
Nikos	A	F	D	B	A	A	D
Tania	B	E	A	B	A	B	C
Constantine	A	F	D	C	E	E	A
Vaggelis	A	F	D	C	C	E	D
Astrid	B	B	C	B	C	B	C
Jacopo	A	E	B	B	C	B	C
Saiorce	B	F	D	C	E	A	A
Peter	B	G	B	C	E	E	C
Karim	A	F	D	D	E	E	A

Doris	A	B	D	C	E	B	C
Omar	A	B	D	C	E	E	C
Niall	B	F	D	C	E	A	B
Luca	B	C	C	C	C	D	B
Swita	B	G	A	B	C	B	A
Rory	A	E	C	C	A	B	B
Romain	B	F	C	B	C	E	B
Michael	B	G	B	B	D	B	C
Sila	B	B	C	C	A	B	A
Bernard	A	A	D	C	E	A	D

Appendix C

An Interview

This is an interview with Ms Doris Rohr, a Research Associate at the University of Ulster. Ms Rohr specializes in art and design in public spaces, and she is interested in the ways perception and experience may be affected according to the context of the space. The interview she kindly provided, took place in Belfast, on the 26th of July 2007.

SD: What is your opinion of having sonic/sound/audio/music embellishments to accompany an architectural space? Note that by music is not implied any relevance to commercial or radio music but rather more to acousmatic/concrete and electro-acoustic music, in the sense that these genres have more abstract forms and are also more kin and flexible for interaction if desired.

> *DR: Silence and sound are very powerful ways of imposing an authority onto a space. This knowledge has been used in many ecclesiastical and spiritual or meditative settings. An example might be the bamboo sound of a rod filled intermittently with water from a constant supply, where the accumulated weight of stored water periodically will make the rod overbalance, and hit the ground below, emitting a sound. Church bells, or chanting are other examples were sound contributes to a heightened awareness of one's own body in space and physical presence, and of silence and its absence. Depending on the purpose of the sound applied, and the purpose of the space, I*

think that sound can contribute positively towards focusing the user of the space towards the functions ascribed to it, or sound can become effectively applied to put a person's mind at ease or greater comfort (this of particular use in environments associated with pressure – prison, hospital, school, airport etc).

SD: Do you believe that the architectural space will be sensed/ experienced differently if sophisticated sound design would accompany it?

DR: Yes, I implied this already in answer given to question 1. To expand: sounds in spiritual buildings can contribute to greater spiritual awareness and ability to reflect. Sound employed in coercive and pressurizing environments, like prison, doctor's waiting room etc, if of a calming effect (i.e. running water sound, fountain sounds etc) can help to relax minds of people using the space.

SD: If the artificial soundscape was interactive (i.e. use of sensor technology like computer vision to alter some of the parameters of the soundscape) do you believe that the experience of being inside the space would be enhanced or not?

DR: This is difficult to say – the examples I have given make reference to authorities imagined, speculated upon or for real, where sounds were to become employed authoritatively to enhance the purpose, or to counteract the negative effects on nervous system associated with coercive institutional spaces. Therefore I think the soundscapes employed authoritatively will probably be more effective for their distinctive purposes, than as if the user of those spaces is left to believe that s/he can *exercise some limited control or have a limited effect on the environment (?) But question mark is meant to indicate that I have an open mind about that – why not test it out with a user group? I wonder however, if a degree of over-stimulation could easily be achieved when interactivity is desired.*

SD: What drawbacks/problems do you suspect that a sound design installation as this one will create to the quality of the architecture itself and also to the quality of living or participating in that space?

DR: This all depends on what type of installation is integrated in what type of building, and on its primary functions. I can see advantages rather than drawbacks in a nightclub environment or in a playschool area, or indeed, if supported through relevant specialists working with such user groups, in an environment where mentally or physically disadvantaged individuals or groups might benefit from the stimulation as a form of rehabilitation for example. Drawbacks I have already referred to in response to a previous question.

SD: What kind of spaces do you think that need to be aurally enhanced (hall-ways, waiting rooms, bathrooms)?

DR: Waiting rooms! Having consulted recently with a particular user group in a coercive environment where prolonged waiting forms part of an experience of disempowerment, the waiting areas need improving, and sound could do so. But how do you consult so that the experience is *positive for a user group? How does one deal with different human preferences and associations – especially if the waiting area is to be shared by a group?*

From my experience – waiting and sound can have very negative connotations (think about telephone trees and waiting for someone to speak to you personally from a call centre – all music becomes tedious in that situation. Thinking about crossing the sea on the Stena line ferry to Belfast – the soundscape provided there is somewhat calming but it sticks to one's subconscious mind and can be irritating.

Bathrooms? Private? Public? Lavatories – could be interesting – can be embarrassing to hear other people's body noises. Airplanes, public transport (with optional use? Optional spaces?). I think prime areas must be hospitals and doctor's waiting rooms, and prisons, special rooms (chill out rooms) in schools or other areas like that – in consultation with people working there, specialists and of course the user groups. Meditation areas, churches – in consultation with those who minister or use them.

SD: According to your experience, do you believe that your clients – with an extra cost – would like to have a space designed as such?

DR: *Who are the speculative clients? If you are talking about commercial premises, then this needs more specific research into user ends and benefits (example might be public transport). This group of clients would only be interested if in the long run this will offer greater sales figures, or enhanced publicity/*

recommendation. You need to target this area separately in a specifically designed questionnaire, after some consultation with relevant organizations.

If there are safety advantages there might be support through grants and one could consult with the police etc on potential areas of benefit.

If you are interested in spaces, which might be supported through charity, or an institutional framework, which to some extent is funded by government, then different means of testing funding are obtainable. In my own work environment surely this would mean a collaborative research grant looking into architecture and sonic application as a disciplinary endeavor, potentially with input of psychology department (?)

SD: Do you think that visual aids (like interactive graphics) would enhance even more the aural perception and furthermore the inhabitancy in that space?

DR: Definitely so – and can be used to guide in areas of human traffic flow (underground, public transport environments etc)

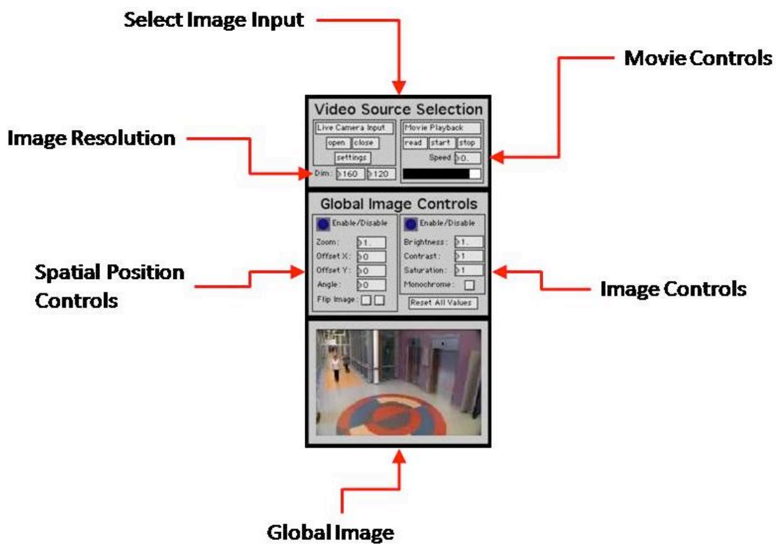
SD: Do you agree with the idea of having technological advancements from interdisciplinary areas embedded in an architectural design, and how do you believe this will help the quality and the aesthetics of living?

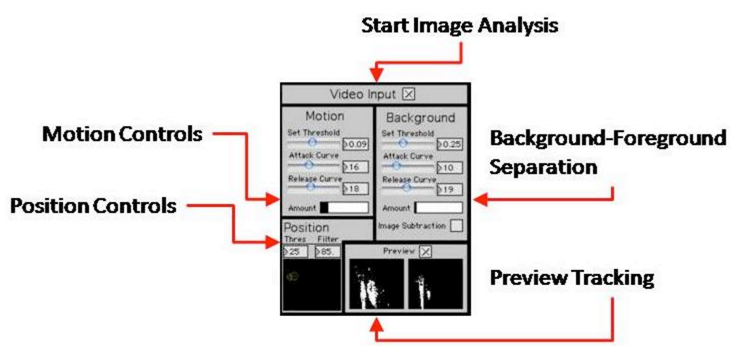
DR: I have no objection to this in principle – providing the relevant research into user groups and ethical implications are considered sufficiently. Quality and aesthetics are very context specific – but I have addressed some examples already above.

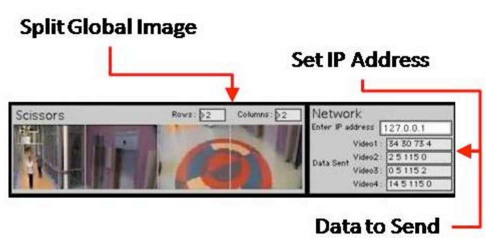
Appendix D

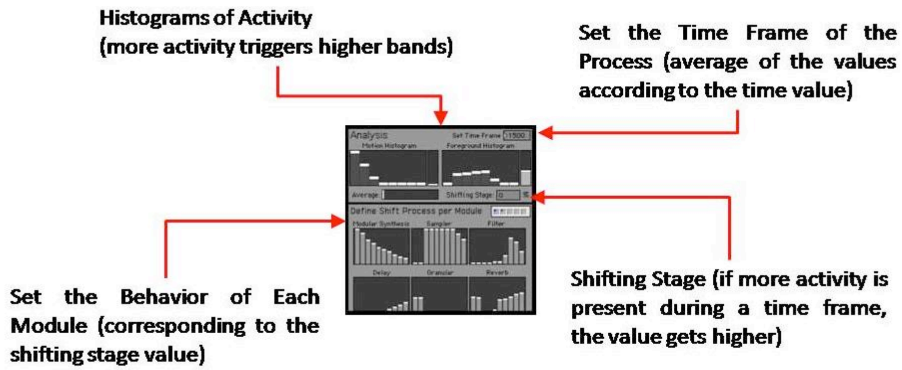
Module Description

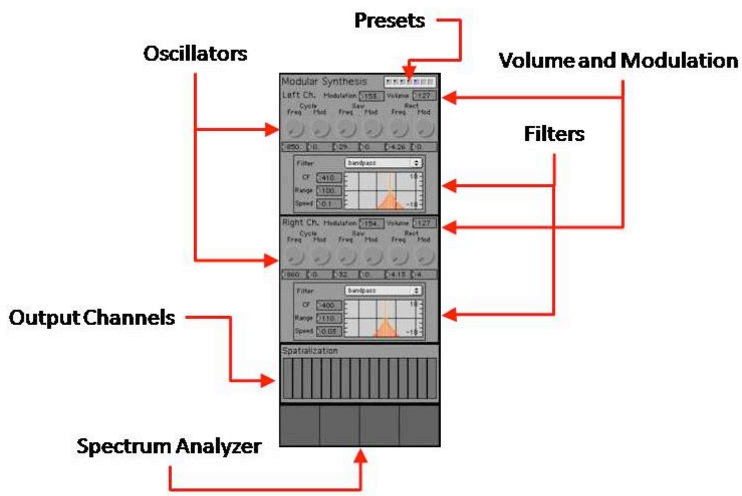
In this section I present a more detailed description for the systems I have developed for this thesis.

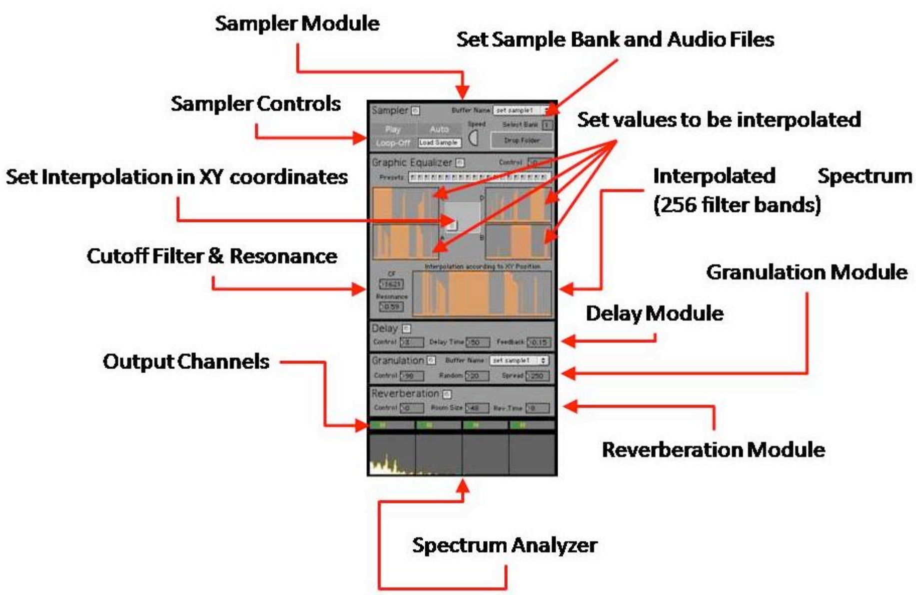







Histograms of Activity
(more activity triggers higher bands)
Set the Time Frame of the Process (average of the values according to the time value)
Set the Behavior of Each Module (corresponding to the shifting stage value)
Shifting Stage (if more activity is present during a time frame, the value gets higher)


Presets
Oscillators
Volume and Modulation
Filters
Output Channels
Spectrum Analyzer


Sampler Module
Set Sample Bank and Audio Files
Sampler Controls
Set values to be interpolated
Set Interpolation in XY coordinates
Interpolated Spectrum (256 filter bands)
Cutoff Filter & Resonance
Granulation Module
Delay Module
Output Channels
Reverberation Module
Spectrum Analyzer

Appendix E

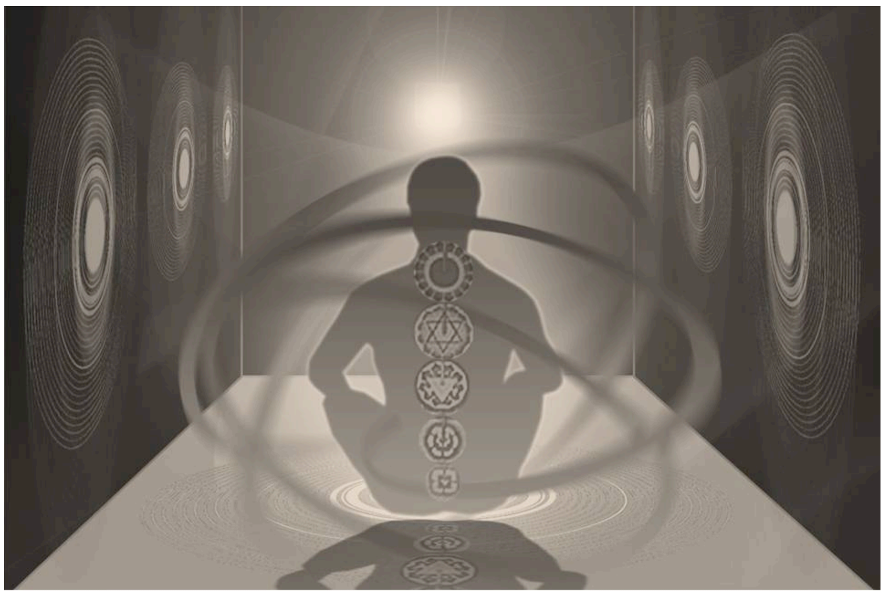
Soundscape of the Hallway

To properly design the hallway, it was important to study carefully its acoustic ecology, and understand the sounds that interact within the space. Following, there are measurements of the noticed sounds.

Automatic Stairs	57 dBA Scale
Ventilation	58 dBA Scale
Automatic Doors	60 dBA Scale
Elevators	59 dBA Scale
People Walking	58-70 dBA Scale
Walking sticks	56-65 dBA Scale
People Talking	58 dBA Scale
Children yelling	63-74 dbA Scale
Plastic bags	60 dBA Scale
Radios from security guards	63 dBA Scale
Wheelchairs	59-65 dBA Scale
Medical Equipment	60-65 dBA Scale
Transportations (Equipment)	62-70 dBA Scale
Outside equipment (with window open)	60 dBA Scale
Building Constructions (Outside)	60-64 dBA Scale
Noise coming from nearest areas	58 dBA Scale

Colophon

This document was prepared with Microsoft Word 2007, and Adobe Photoshop CS3. Column charts were made in Microsoft Excel 2007. Snapz Pro X was used for the screenshots. The text of this thesis was set in sixteen and twelve point Cambria, designed by Jelle Bosma. The chapter titles were set in twenty-two point Calibri designed by Lucas de Groot.



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