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A mobile artistic sonification of wireless networks

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Abstract

The Warbike, a project that sonifies computer wireless networks to a bicycle rider, is presented within the framework of psychogeography, its contemporary counterpart of locative media, wardriving, and the bicycle as symbol and political platform. An account and analysis is presented of the methods and choices for the construction of the device, and the applied sonification techniques.

The central consideration is how sonification can be used to communicate to a participant his movement through the invisible infrastructure of wireless networks. Data from wireless networks, including network activity and encryption status, are sonified to a cyclist through a speaker-enabled backpack powered by a PDA.

Exhibitions of the Warbike showed that participants reacted favourably, and that the chosen methods of sonification properly conveyed their movement through the wireless communications infrastructure.

Keywords: locative media, wireless networks, wardriving, bicycles, sonification, sound art

“The view from the outcropping was stunning. The village had grown to a town, fast on its way to being a city. A million lights twinkled. The highway cut a glistening ribbon of street lamps through the night, a straight line slicing the hills and curves. There were thousands of people down there, all connected by a humming net-work—a work of nets, cunning knots tied in a cunning grid—of wire and radio and civilization.”

Cory Doctorow, from Someone Comes to Town, Someone Leaves Town (Doctorow 2005)

Contents

1 Introduction

This thesis chronicles a sonification project that is the product of accidental discovery, and a certain zeitgeist of the present era—the communications revolution.

People are developing a greater dependency on using communications technology to run their lives and their businesses (International Telecommunication Union 2003). It is now almost unthinkable that someone would not have a mobile phone, or at least an e-mail address. PDAs, iPods, and other mobile devices have become an integral part of our cultural, business, and personal landscapes. With the new power of communications comes the responsibility to maintain security and privacy, if the public wants it.

The meaning of the word “hacker” has changed from its original roots within the technology community. It originally meant someone who was extremely resourceful at getting technology to perform in useful ways for which it was not designed. To the public, the term now generally means someone who would maliciously gain access to private systems or information—in effect, a trespasser, a pirate; if not a criminal then at least someone with questionable privacy ethics. The popularisation of the term into the public sphere came with films such as 1983’s *War Games*—starring Matthew Broderick as a teen who accidentally gains access to military information systems—and the very public FBI manhunt for famed hacker Kevin Mitnick, who did similar things in real life (Shimomura, Marko 1996).

As computers and networks become more commonplace appliances in our homes, the public is looking for simpler ways to integrate the technology into their lives. Industry has answered with 802.11 wireless ethernet networks (Wi-Fi Alliance 2005).

The public is happy to accept this new technology that no longer requires them to run cables through the walls of their homes and offices, without consideration for the repercussions of what it means to be “wireless.” Perhaps if these networks had been dubbed “broadcast,” the users might think differently about where and how their network is being made available and accessible.

I believe that the burden to educate consumers about the potential privacy dangers of these networks should rest on the manufacturers of such equipment. The fact that networks are not locked and encrypted by default shows either complacency on behalf of the manufacturers, or an assumption that the consumers are incapable of understanding how or why networks should be encrypted. At the very least, it is responsible business ethics to give their customers educational or instructional information on protecting their purchased systems.

The consumers appear not to be aware that their information is being broadcast into public space. Their private data, financial information, passwords, e-mails, love letters, etc. are being broadcast into their neighbours' houses, and onto the street, often without so much as even a thin veil of protection.

My own personal experiences Wardriving, the “geek” hobby of examining wireless networks available from the streets—and a large influence and starting point for this project and thesis—show that on average at least half of available networks are unsecured and frequently the number is closer to two thirds.

The troubling aspect of this situation is that the tools and knowledge needed to do any real damage—either malicious intrusion or the acquisition of private information—are not only readily available to the public, but included in most modern consumer computer systems. No longer need we be afraid of the occasional computer literate hacker with knowledge and equipment far surpassing our own; the damage can now be done by our seemingly innocent elderly neighbour.

1.1 The beginnings of the exploration

The Warbike project originally began upon accidental discovery that the popular Windows Wardriving tool, Netstumbler (Milner 2005), had an option to send MIDI (MIDI 2005) musical information. Once it had been discovered that it would send information on the strength of networks in the vicinity, a computer programme was written to create simple squeaking sounds based on the strength of the signals.

Recently relocating to Europe had given me my first experience of a more bicycle-oriented urban culture. In Canada bicycles are something that children ride before they can drive a car. I had been actively biking, trying to embrace this new, healthy lifestyle.

When the programme was written to turn the networks into sound, it was tested on a running laptop in a backpack during bicycle rides. What was experienced during these rides was what I would later recognise as a psychogeographical experience of the neighbourhoods.

The knowledge of the placement of wireless networks in a neighbourhood is not simply empiric, it changes one's perception of that space. The uncovering of these invisible communication webs alters the way that one perceives and associates with the area. Certain corners or areas could no longer be passed without wondering about the owners and the activities of the networks that had been found.

The Warbike project was an effort to share this experience with others. There were two specific design problems that needed to be addressed in the project development. The first was the portability of the project. A laptop in a backpack was not practical, and battery life was a major concern. Fortunately, that was solved by my involvement with the Ottawa-based artist-run centre *Artengine*, which had generously loaned the use of a Hewlett Packard iPaq during my appointment as artist-in-residence in July of 2005, funded by the Canada Council for the Arts.

The major design issue became the central exploration of this thesis. To that point, several proof-of-concept programmes to sonify the networks were written. But the purpose of sharing this experience was also to educate the participants about wireless networks. There had to be more effective programme designs to communicate this unaddressed situation. The search became: how can sonification be used to to communicate to a participant his movement through these invisible communications infrastructures?

Presented in this thesis is an exploration into solving that sonification issue from conceptual, ideological, and practical standpoints.

A prototype of the project was displayed during the residency at Artengine, and later at the Big Love gallery in Göteborg, Sweden. Responses were favourable, and reactions much stronger than had been anticipated.

I had been developing the system for so long that the initial premise, what it was that was trying to be achieved, had almost been forgotten. I had forgotten the “ah ha!” surprise moment one gets when discovering the networks in such a manner.

The reactions of the participants confirmed that many aspects of the project had been developed properly to achieve the goal of education about the prevalence of the networks. But it left many questions about how to further develop the project. Those issues are dealt with in the final section of this paper.

1.2 Structure of this thesis

This thesis begins with a description of the historical and ideological path leading to the current field of *locative media* and *psychogeography*, beginning with the description of the *Flâneur*, through the Situationist *dérive* theories of Guy Debord.

The project is based on several important methods and concepts, aided by locative media and the aims of psychogeography. The proliferation of wireless networks and their implications, as well as artistic projects highlighting this, are discussed. Sonification, the use of sound to convey data, guides the production of the work. And finally, the bicycle as medium and political tool is explored.

Following that is an overview and analysis of the Warbike project, from its motivation stemming from psychogeography, to an analysis of the technology and methods used to create it.

This project provided many challenges not in only in the conceptual challenges of programming, but in the physical challenges in terms of programming for a PDA and the limitations this imposes on one’s ability to create a coherent product. The question is no longer the simple “how is the goal achieved?" but becomes the more onerous "how little must be done to achieve the goal?"

Finally the thesis finishes with analysis of the efficacy of the Warbike, possible improvements to better achieve its goal, and future work in this field.

2 Historical placement and ideological ancestors

The Warbike project addresses concerns, and benefits from previous work by many individuals, who all provided a long ideological history upon which the project is based. It is important to understand the origins of these ideologies, theories, and techniques to understand why this project was undertaken. This section will discuss the histories and motivations behind psychogeography, its philosophical ancestors, and its modern-day technology-based descendants; the bike as political tool within the cityscape; and the medium of the project, sonification.

Throughout this discussion, examples of projects relating to these themes will be presented, to better explain where the Warbike project sits among previous artistic endeavours.

2.1 Flâneur tradition

The *Flâneur* is a literary character of 19th century Paris. He appears earlier in the works of Balzac and Alexandre Dumas, and later as a slightly different character in modernist writers such as Aragon and Charles Baudelaire, and in the works of Walter Benjamin (Shields 1994).

The character of the Flâneur provides a kernel for what would later be coined *psychogeography* by Guy Debord and the Situationists. The Flâneur is not a philosopher or artist, such as his idealogical descendants, the Situationists, nor has he the same purposes as they will later have. But he marks the beginning of the process of observing, understanding, and cataloguing the activity of urban spaces.

The Flâneur is a product of the metropolis of 19^{th} century Paris, the megalopolis that is the urban centre. The Flâneur is, in his essence, an observer of people. He is present in the crowd, but not a part of it. He is disconnected from from the ebb and flow of people, impartial (Lane 2004).

Neither is the process of the Flâneur merely strolling. What the Flâneur does separates him from all those within the crowd. He walks through the crowd observing their actions, their movements, their faces, anonymously (Manovich 2001).

The Flâneur has a relationship to the city and its inhabitants that is analytical. Flânerie is a social process, in that it plays off of the society at large. It is site specific, the site of the interior and exterior public spaces of the city. It is part of the social process of inhabiting and appropriating the urban space (Tester 1994). The Flâneur takes the space of the unfamiliar, the city, public, and treats it as a space as familiar as a room (Benjamin 1986).

The important aspect of the Flâneur is his awareness of public space. It is this re-evaluation of urban spaces not as man-made constructions infringing upon natural systems, but as complex systems in and of themselves.

2.2 Debord and the Situationists: the dérive

> *"Men can see nothing around them that is not their own image; everything speaks to them of themselves. Their very landscape is alive."*
>
> *Attributed to Karl Marx by Guy Debord* (Debord 1958)

Discussion of the Flâneur is merely the prologue to the study of people in urban spaces. It was through the Flâneur in 19th century Paris that intellectuals began to conceive this effort.

This practise was given a name—*psychogeography*—and turned into a deliberate act, not merely the amblings of literary figures, by the Situationists of the 1950s and 1960s, as championed by Guy Debord. Psychogeography is the mapping of psychological space to physical space. The term was coined by the Situationists and was their most active pursuit.

In Debord's psychogeography manifesto of 1958, *Theory of the Dérive,* he outlines his main tool employed to understand urban spaces, the *dérive*. It is important to be aware that psychogeography focusses on urban spaces. As it deals with people in space, non-urban spaces are particularly uninteresting from a psychogeographical point of view, as Debord remarks upon when he mocks early surrealist wandering experiments in the open country (Debord 1958).

If one considers the city not as a construction of static streets and buildings, but as an area in which there are eddies and currents of human activity and interest, the basic concepts of psychogeography and the dérive begin to emerge. Debord states that “cities have psychogeographical contours, with constant currents, fixed points and vortexes that strongly discourage entry into or exit from certain zones” (Debord 1958). He speaks of geographical and economic factors, and the image that residents impose upon their neighbourhoods that create these paths within a city.

A dérive is not a stroll, but a very deliberate walk, where the walkers “let themselves be drawn by the attractions of the terrain and the encounters they find there” (Debord 1958), much as a leaf in a stream.

2.3 Why psychogeography?

Why is this study important? Psychogeography has become a current buzzword, with many projects focussing on this theme (some of which will be discussed further on). As humans are being drawn to large urban centres it is becoming extremely important to analyse these structures and control their development in ways that benefit their inhabits, rather than letting the cities grow and sprawl haphazardly as they have in the history of human settlement and habitation.

The very profession of the Urban Planner is one who designs cities for people, to optimise the space in favour of the citizens. “Sylvain M.” in Cherubini and Nova's *To Live or To Master the City* (2004) speaks of the urban planner's approach to space. Space is not merely the container of the city to hold buildings, it is also the means by which citizens move.

The city is a social fact, and its perception is a social fact, as stated by Milgram in *Psychological Maps of Paris* (1976). This opinion is echoed again and again by those such as Sylvain M. and Augé: “a place is defined by identity, relation, and history. On the other hand a space that has no identity and can't be described neither relational nor historical, one would call a non-place” (Augé 1985). This is the transformation of the urban planners “space” to *place*. “Place is space with meaning” (Erickson 1993). This place is important to the inhabitants. As Sylvain M. states, space is related with feelings, connected with freedom, with the sense of connection with the community, and a vital place for movement (Cherubini, Nova 2004).

Ultimately, knowledge of the place will help us to develop a sensibility in regarding the urban space and changing perspective and attitude toward the city, this collection of common utilities and spaces that belong to everyone. Understanding the experience of the city will empower not only the urban planners to appropriately design for humans, but will empower the citizens to better understand their own place within these structures which may seem labyrinthine and overwhelming. This knowledge will improve city consciousness and engagement (Cherubini, Nova 2004).

2.4 Beyond Debord: Locative Media

Debord can barely hold back his contempt for earlier psychogeography experiments by the surrealists and his own contemporary Pierre Vendryes when he refers to their explorations as “imbecilities” (Debord 1958), as if he himself had unlocked the magic algorithm required to truly expose the life behind the geography.

Debord seems slightly ungrateful to and unaware of the importance of the work of his predecessors, and even his contemporaries, in his development of the dérive and other psychogeographical tools. It is impossible to ignore the profound importance to the field that Debord created, however it is important to understand why his experiments are limited in their ability to truly achieve the goals set out by Debord himself, just as the surrealists’ experiments could not have achieved their goals.

Debord’s work is, in a sense, solipsistic. By limiting the dérives to the tools of humans on foot, the data available to explore the supposed true nature of the space is limited to the senses of the humans. As scientists have been aware for years, there is more to the universe than that which can be perceived directly by humans.

Lack of sensors notwithstanding, humans are fallible. Our ability to accurately synthesise the data we receive from our own senses without the aid of statistical analysis is inexact, statistically and factually. Humans' frequent difficulty in decoding our own social interactions is just an example of our fallibility with our senses. Imagine trying to fully understand every nuance of the hidden and active life of a piazza merely by standing and watching. It is evident that Debord's methods would never reach his desired goals.

Out of the efforts and experiments of Debord and the Situationists comes the field of *Locative Media*. The psychogeography movement attempted to achieve a deeper understanding of the functions of urban space, not simply the physical structures of buildings and pathways of movement, but the ways in which these structures create, house, and foster life within the city. Locative Media is an attempt to answer the same questions as the Situationists through the use of mobile, location-aware technologies. Technology can help to bridge the gap between people and their city, or as a "proxy to improve awareness of city appropriation by involving people in different kinds of activities" (Cherubini, Nova 2004).

This technology as proxy shapes our perception of our environments (Paul 2003). Theresa de Laurentis says that technology "shapes our perception and cognitive processes, mediates our relationships with objects of the material and physical world, and our relationships with our own or other bodies" (Flanagan 2005). Psychogeography begins to uncover the two layers of our environment. There is the physical layer, which is frequently the only layer described by the casual observer. On top of that physical layer is the information layer. The information layer encompasses all activity, seen and unseen, within that physical space. It is the failure of the traditional map to truly communicate this contextual information, this human geography of the space (Nova 2004). As Magnus

Haglund states, the map is one way to fantasise how a place might look (Haglund, Schneider 2004).

Psychogeography distinguishes between the physical layer of infrastructure, and the human layer of social interaction (Nova 2004). The tools of locative media attempt to recreate the informational landscape of the real-world landscape (Gutwin, Greenberg 1999).

In a sense, psychogeography and locative media are about creating alternative maps. The city is full of cues and signs that can be decoded and turned into something meaningful (Cherubini, Nova 2004). Plant (1992) discusses the “remapping” of the urban landscape, implying the creation of alternate maps to better understand an area. Paola V., an interview subject in *To Live and Master The City* (Cherubini, Nova 2004), discusses using various perceptions to cognitively build an image of the city, and to compare different mental maps or internal representations to come to a common view of the city.

To return to the concept of technology as proxy, Lane (2004) states that through technology “we have the ability to perceive through others’ eyes.” Technology not only allows us to overcome sensory fallibilities, as was previously stated, but to allow some kind of telepresence, or teleperception of others within and affected by the spaces that are studied.

The power of the technology of locative media is that it is mobile, and becoming increasingly ubiquitous. The cellular phone is transforming from its history as briefcase with telephone receiver, to a pocket-sized device, camera, and mobile computing platform capable of running and executing code of modern programming languages such as Java and Python.

“Mobile media has made it possible for the practises of the technologically savvy to twin with what were previously the every day practises of the French philosopher” (Lane 2004). And here we see our connection to Debord. Locative media acts as philosophical equaliser, allowing more than just a small group of intellectuals to truly understand the efforts of the Situationists.

2.5 Wireless Networks and wardriving

Wireless computer networks, dubbed “WiFi,” have become more prevalent as the dominant method of networking between computers. WiFi encompasses all networking that follows the IEEE 802.11 standard of networking (Wi-Fi Alliance 2005).

Wireless networks are becoming a political tool for free speech activists realising the rallying cries of the early days of the internet—to empower every person with a voice in the interest of freedom of speech.

Many cities around the world have community efforts to arrange free, city-wide wireless coverage. This concept is even entering a cultural zeitgeist, as shown in Cory Doctorow’s novel of 2005 *Someone Comes to Town, Someone Leaves Town*, where the main characters attempt to organise free networks blanketing Toronto, Canada.

Opposition to these efforts is met in the form of industry lobbyists attempting to make free wireless access illegal, as reported in 2005 (Rizzo 2005). In November of 2005 Lawmakers in Westchester county in New York state in the United States were considering illegalising open wireless networks that do not provide proper protection from intrusion (McCullagh 2005).

The discussion of security in wireless networks is an important one.

Wireless networks provide some form of encroachment of private property, or private space—the network—onto public space, the streets, or others' private spaces.

Wireless networks have never bee invulnerable. First one must consider that any consumer-grade wireless router comes with the encryption off by default. A quick survey of networks in any neighbourhood, be it business or residential, will show that the majority of networks are open. Consumers are either unaware of the dangers of leaving the network open, or do not know that the network can be closed.

The basic form of wireless encryption, Wired Equivalent Privacy ("WEP"), was thought to be relatively stable. At an Information Systems Security Association meeting in Los Angeles in 2005 the American FBI demonstrated a process to break a standard 128-bit WEP encrypted network—the strongest form of WEP encryption—in five minutes, using freely available software tools (Humphrey 2005).

A newer standard called Wi-Fi Protected Access ("WPA") is currently available on newer wireless equipment, and it's successor standard of WPA2 is also available on newer hardware.

When new technologies are being discussed, analogies are frequently used in an attempt to provide some clarity in the situation, to describe or understand the *new* in a familiar or known experience. Can it be said that a network is analogous to a person's house?

As stated by Susan Ness (1999), Commissioner of the United States Federal Communications Commission: the electromagnetic spectrum is considered public public resource and right, in essence a public space, and portions of that spectrum are licenced to industry—many countries also function in this manner. Users of the WiFi spectrum are appropriating this public space, laying claim to it, and turning it into a private space by transmitting personal data or encrypting the network. Nonetheless, this private space is broadcast onto the public space. An open network is not a house with its door unlocked; it is a broadcast, with its own set of very unique qualities.

This pseudo-private space is a blending of what Sylvain M. speaks of when discussing understanding the perception of the city, the personal/inner level and the social/outer level (Cherubini, Nova 2004). This networked communication becomes a personal level superimposed onto the outer level, unbeknownst to those using the networks. The impact of this technology mutating the public and private space allows us to reassess what public space is (Tuters 2004).

These security concerns are exploited in several projects and products, serious products as well as artistic fancy. Christos Mias of the University of Warwick devised WiFi-proof windows (University of Warwick 2004), a metal grid that could be embedded in glass windows to prevent the transmission of wireless signals. The obvious applications of this technology are to prevent industrial espionage and protection of sensitive data. No longer is wireless network security the obsession of paranoiacs, but important to companies themselves.

Jonah Bruckner-Cohen's (2003) *WiFi Hog* is an ironic device that prevents all users but the WiFi Hog user from accessing a wireless access point. Bruckner-Cohen sees it as addressing the issue of private space intersecting with public space. If the private space is made available, what are considered ethical and acceptable uses of that space?

2.5.1 Wardriving

The Warbike project is heavily influenced by the “geek” hobby of wardriving, which is the practise of searching for wireless networks in urban areas, normally using a car. The Warbike project borrows its name from the practise.

Wardriving is a form of psychogeographic analysis of an area, although the geek practitioners may not be aware of it. Its practise was brought to public attention when in 2002 a network security company published a map of Toronto, Canada’s downtown core and all networks, encrypted and unencrypted, in the region (Slashdot 2002).

Suddenly the perception of the downtown core of the city changed. What was previously a simple business district, busy with the activity of people, was now perceived as bustling with invisible and vulnerable data communication.

2.5.2 WiFi aware accessories and fashion

In recent years designers and artists have been addressing similar ideas as the Situationists in the form of wearable accessories that integrate into the fashion of a user. They could be viewed as simpler, more elegant versions of wardriving than using a PDA or laptop, but the psychogeographical experience of walking a neighbourhood while wearing active accessories or clothing cannot be discounted.

Karen Lee’s (2004) thesis project of *Hotspot Bloom* is a mechanical flower blossom that indicates the presence of wireless networks. It has had several iterations that achieve essentially the same function. One version blooms, the petals of the blossom open outwards, when a network is present. Another version simply has an RGB LED to display the presence and signal strength of nearby open networks.

Darsha Hewitt's *Hotspot Twinklers* (Hewitt 2005), seen in Figure 2.1, function in much the same way as Hotspot Bloom, by displaying the presence of any wireless network through LEDs on the toes of a pair of shoes.

Figure 2.1.: Darsha Hewitt's Hotspot Twinklers. *Photo courtesy of the artist.*

WiFisense (WiFisense 2003) is a satchel or purse with a matrix of 64 LEDs embedded in the side that will flash patterns to communicate the presence and availability of nearby networks. Similar also is Richard Etter and Diana Grathwohl's *AwareCuffs* (Etter, Grathwohl 2005), shirt cuffs with LEDs where one would place cuff links, that display the presence and quality of networks based on the colour of the LEDs.

These accessory projects all provide distinctly visual cues as to the presence of networks, and generally approach their communication in much the same way: light on if there is a network presence, colour or pattern denotes the quality of the network.

2.6 Sonification

Sonification is the method that the Warbike uses to convey the information of the networks to the participant. The practise is the attempt of representing data and data relations using non-speech audio. It is the “transformation of data relations into received relations in an acoustic signal for the purposes of facilitating communication or interpretation” (Kramer, et al 1999).

Sound has long been used as a medium for communicating emergency messages or warnings (Wickens 1998). Pre-dating the use of the word sonification have been many devices that use sound to convey information, such as the Geiger counter, sonar, the auditory thermometer, and various medical displays (Kramer, et al 1999).

An early example of a more complex and purpose-oriented sonification was performed by Forbes (1946) where aspects of aeroplane navigation, such as altitude and compass heading, were mapped to various tone parameters, such as pitch and pan. It was found that pilots were able to perform very well without visual information with minimal training on the system.

Sonification is increasingly being studied not merely as a warning system for data whose trends can be predicted, such as blood pressure, but to study data where visual display is unable to yield results. The Voyager 2 spacecraft mission developed a problem while rounding Saturn. Visual displays were unable to locate problems. However, a music synthesiser was used to sonify the data and yielded a “machine gun” sound, leading to the discovery that the problem was caused by collision with micrometeoroids (Kramer, et al 1999). After months of unsuccessful observation of oscilloscopes, researchers David and Packard were able to locate the “Quantum Whistle” by sonifying their data, providing the first evidence of the oscillation of particle currents between two coupled macroscopic quantum systems, as predicted by quantum theory (Kramer, et al 1999 and Pereverzev, et al 1997).

There has been surprisingly little work done exploring the efficacies of various sonification models. In the past, methods have merely been applied and tested according to their functionality, but not compared to determine more efficient methods. This paper will not attempt to answer those issues, either. The possibilities of the field of sonification are extremely broad.

Humans are dominantly visually oriented, and therefore are unaccustomed to receiving absolute information aurally. Although humans use their ears to receive information about events and spaces around them, the perception and reception of that information tends to be processed in more of an intuitive manner.

Sonification is also being explored as an aide for the blind, replacing faculties lost either by accident or disease, or those blind from birth. *The vOICe* is a sensory substitution device that exploits the plasticity of the brain to reorganise itself and perceive auditory stimulus as visual stimulus (Merabet, et al 2005). The vOICe functions by converting frames of video into repetitive one second additive frequency sweeps, representing the shading of areas of the image through the strength of different sonic frequencies. Although the product is still being researched and tested, currently several blind adults are successfully using the device as their primary means of visual perception. The benefits of this are many, not the least of which is the ability to see without the need for brain or retinal implants.

The research of Sonification is also a convergence point for many fields. Its medium has a very strong connection with areas quite unrelated to research and science. Sound and music have long been used for emotional purposes. Music has a long history within virtually every spiritual tradition. Its use within opera and film soundtracks to manipulate the emotions of the audience is well-established. Sonification brings together components of psychoacoustics, art, engineering, and many other fields.

There has been significant use of data for musical purposes that are not as rigorous as the pure data-display endeavours of the scientific community. All of these artistic endeavours fall somewhere in the grey area between hard data-communication, and convenient and interesting-sounding random number generation.

Composers have a long history of incorporating data into their compositions, dating at least as far back as the medieval and renaissance periods. Perhaps most famous is Guillaume Dufay's *Nuper Rosarum Flares*, a motet created for the dedication of the Cathedral of S. Maria del Fiore in 1436, later discovered to have musical structures matching the ratios of architectural measurements of the same cathedral, and possibly King Solomon's temple (Warren 1973 and Trachtenberg 2001).

Bob Sturm's (2003) sonification of ocean buoys is perhaps one of the most well-known current examples of artistic sonification. Sturm used the data from buoys off of the west coast of the United States as basis for sound synthesis.

It must be noted that the output of sonification is extremely malleable—with the proper treatment, any data can be made to achieve the same results. In practical sonification there is a very specific objective in mind. Either the sonification is meant to convey something objective—when the pitch goes up, the temperature is rising—in which case the data treatment is determined to yield a specific result, or the sonification is meant to uncover trends and relationships in data sets that would not otherwise be possible. In both cases there is a very concrete objective to the sonification.

Artistic sonification does not have those restrictions, it has an ultimate artistic licence, at the discretion and inspiration of the creator. Sturm feels that the results of his sonification sound particularly oceanic, and he is probably right to assume that they do. But with the appropriate mappings they could have been made to sound like something quite unlike the ocean.

This represents the broad spectrum between objective, practical sonification and artistic endeavours. The Warbike sits somewhere in between these two poles. Its objective is not to create a fully composed piece of music from the wireless networks, but the sonification decisions will be chosen to highlight some very specific information that is already known to exist about the presence of networks and their activity in urban centres.

2.7 Sonic City

> *In this project, our intention is to break out of traditional contexts for music creation to explore creative possibilities within local surroundings and mundane activities. Wearing Sonic City, anyone can experience a simple walk down the street as an expressive act, a path through the city as a personal composition. As a complement to lived urban experience, it is an intimate soundscape intended to enhance perception and encourage new uses of the urban landscape.*

(Gaye, et al 2003)

Sonic City (Gaye, et al 2003),shown in Figure 2.2, is a project of Gothenburg, Sweden's Viktoria Institute and the Interactive Institute's Play studio. It is perhaps the closest contemporary effort to the Warbike, ideologically and practically. It explores the field of psychogeography and locative media also through sonification of a city space.

Sonic City differs from the Warbike in that it is intended to be a platform for music creation, or co-creation with the city as either interface or co-performer. Through many kinds of sensors, aspects of the city are converted into generative musical material, providing a kind of mutating composition.

Unlike the Warbike, which seeks to use only the wireless computer networks in the environment, Sonic City has a wealth of different sensors used to interpret the environment.

Presumably, if one wants to develop an holistic interpretation of the city, the more the merrier is the appropriate attitude when choosing sensors. Current sensors on the device include a light sensor, microphone, metal detector, accelerometer, temperature sensor, and pollution sensor.

Figure 2.2.: A Sonic City *user. Photo from the Sonic City website.*

Both projects seek to allow the user to rediscover areas of a city that might have otherwise gone unnoticed. With the Warbike, the participant may discover new communications activity in an area, a symbol of a lively place that may not outwardly give the appearance of being active. Sonic City essentially establishes sound profiles for similar environments, assuming the sensors will give similar results in those environments when one returns there.

There are plans by the researchers to include even more sensors, such as measuring the participant's heart rate, ultrasound, electromagnetic sensors, and atmospheric pressure. The project appears to be moving from simple urban sonification to an entire audio-based augmented reality, a cyborg-dérive machine.

2.8 The Bicycle

The bike is a curious platform on which to base the project. It could be said that the Warbike on foot would be analogous to the sound-art practise of the Soundwalk (Westerkamp 1974), walking an environment specifically listening to the sounds native to that space.

The use of the bike came initially by happenstance in the initial wireless experiments. The justification for the bike is something that came later after experiencing the early Warbike experiments, and the bike's role within the city.

Specifically, there is a disconnect between the ways in which North Americans and Europeans approach the bicycle. North American culture is very car centric. One need only look at the design of cities, inadequate public transportation systems, and the phenomenon of urban sprawl to understand that it is assumed that citizens have access to a cars (Statistics Canada 2005).

The pro-car mentality was evident in my childhood, where bikes were things that children rode before they had access to a car. Adults without cars were seen as unsuccessful or eccentric.

Citizens are fighting to take back their cities, championed by advocates such as Jane Jacobs, and her 1961 urban planning manifesto *The Death and Life of Great American Cities* (Jacobs 1961). Bikes have become a politically charged symbol in this fight to reclaim their cities. The bike turns out to be a perfect symbol for a number of causes celèbres.

Recently the *Critical Mass* (Critical Mass 2005) bicycle protests, originating in San Francisco but since flowering in many locations worldwide, have been an active voice in urban space and transportation reassessment. Under the slogan "we aren't blocking traffic, we *are* traffic!" cyclists gather as a mass once a month on a city's streets in a cycling equivalent of *Reclaim the Streets!* (Jordan 1998) The movement has had many opponents within various city administrations, publicised by a series of mass-arrests in New York City and various lawsuits by riders in response to excessive force by police, and the city to ban the movement (Bluejay 2005). It should be noted how *important* this issue of cycling must be if thousands of riders are sufficiently engaged to band together once a month, and politicians feel it necessary to arrest of them.

Bikes Against Bush (Kinberg 2004) was a protest performance during the Republican National Convention in New York City in 2004 before the American federal election. The device was an attachment to the rear of a bicycle that would lay white chalk, the same chalk used to mark sports fields. The attachment would write messages on the cement using the chalk according to messages sent wirelessly to it via the project's website. The project never got to function during the intended convention however, as Joshua Kinberg, the creator of the device, was arrested during an MSNBC interview and had all of his hardware confiscated and was arrested on graffiti charges, despite having made no marks on the streets. The arrest was most probably a political action, and also happened near the same time as the Critical Mass arrests.

Yuri Gitman's *Magicbike* (BBC 2004) is a mobile hotspot built onto a bicycle. The bicycle acts as a WiFi point that functions by relaying an internet connection provided either by a cellular phone connection, or other nearby available access points. The project, also based in New York City as with Bike Against Bush and the recent Critical Mass arrests, shares much in common with the *NYC Wireless* (NYC Wireless 2005) initiative, and other similar initiatives worldwide, to free WiFi access. However, Gitman sees the bike providing more subversive and activist-related uses. “Magicbikes are perfect for setting up adhoc Internet connectivity for art and culture events, emergency access, public demonstrations, and communities on the struggling end of the digitaldivide” (Schott 2004). The Magicbike, Critical Mass, and Bikes Against Bush all show the bicycle as a political tool and symbol for activism and reclamation of urban spaces.

The bike has also been used as a platform for connectivity proliferation. Researchers at the Kanpur-Lucknow Lab at IIT Kanpur have developed the *Infothela* (Kanpur-Lucknow Lab 2003). Infothela is a standard rickshaw bike with a fully functioning computer terminal connected to the internet via a 802.11 wireless antenna. The rickshaw was used presumably as an extremely mobile and manoeuvrable vehicle that could access regions that cars could not. Infothela is about more than simply providing internet access to the poor, the creators see it as a means of empowering the poor in rural regions of India, who do not have access to communications technologies. It is an information source for the poor to educate themselves. The creators also see it as a portable medical station, able to power mobile medical devices and provide information to caregivers in the communities who would otherwise be without.

Figure 2.3.: Karen Lee's Hotspot Bloom. *Photo from Hotspot Bloom's website.*

Bikes are not new to the world of music generation. The *MIDI Bike* (Romaine, Roper, Walters 2001) project from CCRMA at Stanford turned a bicycle into a device for controlling electronic music equipment. Information from the wheel velocity, handle bar angle, gear shifter position, and handbrakes was turned into useful information to trigger and control musical events. Applications for the bike were as a simple controller from a drum machine, and navigation through a virtual acoustic environment.

As a North American I see something essential about the bicycle and its mediation of humanity within urban centres. The previous fashion accessory projects, such as Hotspot Bloom*,* seen in Figure 2.3, or the Hotspot Twinklers were very much pedestrian focussed. As such, the participant has a very different relationship to the space.

A pedestrian's relationship to her environment is much slower than a cyclist. The pedestrian's ability to cover ground is not nearly as great as that of a cyclist. Part of the purpose of the Warbike is to achieve some sense of awareness of the character of neighbourhoods. The speed at which a bike travels enables the participant to have an immediate relationship with, and feeling for, a large stretch of road and its neighbourhood.

It is the hope that by utilising the bicycle as the vehicle for this kind of WiFi mapping of the urban space that a compromise can be drawn between a car and a pedestrian. A bicycle goes fast enough to cover large areas of a neighbourhood, but not too fast to disassociate the participant from the neighbourhood. There is no windshield, further allowing the participant a connection with the space. It is vitally important that the participant feel in some way connected to his environment, otherwise there is no connection to be made between the discovery of the network traffic and the space in which he may find himself.

3 Preliminary experiments

The process of arriving at the final result of this project was the product of a series of personal little experiments into the world of wardriving. The project would not have reached the final stage had these exploratory steps not been taken.

3.1 Warwalking: Richmond Hill

Initial experiments in any kind of WiFi exploration happened in the neighbourhood in which I grew up, in Richmond Hill, Canada, forty kilometres north of Toronto. In the summer of 2003 I had purchased a WiFi card and was curious to take a look at what this suburban, residential neighbourhood had to offer.

Netstumbler was used as the wireless sniffer, as that seemed to be the most common and accepted tool for wardriving under Microsoft Windows at the time. A harness for the laptop was created so that the streets could be walked while the screen was still visible.

After walking through these streets that I had been walking, biking, and playing on my entire life, a sense of uncovering an entirely unknown facet of the neighbourhood was developed. What had previously seemed like entirely normal stretches of street, or areas that held some sort of personal significance, suddenly took on an entirely different meaning as “secret” networks were discovered. Secret in that they were invisible and unknown to any who did not make the effort to seek them out.

More significantly, more than half of the networks were unencrypted, which certainly seemed to fit with what was stated in the Naked Toronto report (Slashdot 2002) released about a year earlier.

Future walks without the computer through the neighbourhood started to take on a very special quality. It was as if the streets carried more information than was readily apparent. Certain houses could no longer be passed without acknowledging features such as their network's manufacturer or name. This neighbourhood where I had grown up, the familiar streets on which I had played for many years, were suddenly new again, as if I had just moved in.

3.2 Warcycling: squeak

The second experiment is a direct ancestor to the current project and started its idea germinating. In the fall of 2003 I relocated to Göteborg, Sweden. Göteborg is a bike oriented city. The entire downtown, and much of the surrounding area has dedicated bike paths alongside the roads. This was entirely unheard of to me, having grown up in a suburb of Toronto, where, aside from bike couriers downtown, there was no significant bike culture.

I purchased a bike and daily would ride to and from school on the island in the north of Göteborg called Hisingen. The path would be through residential areas populated by low apartment buildings, and then through the industrial park of Lundby Strand and Lindholmen.

To get a feeling for the neighbourhood, Netstumbler would be turned on and my laptop left in my backpack during cycling trips. A list of most of the wireless networks along common roots was eventually compiled. The findings in term of the amount of networks that were unencrypted were extremely similar to what had been observed with the warwalking promenades in Richmond Hill.

While looking through the settings of Netstumbler, an unusual option for MIDI was discovered. It turned out that Netstumbler will send out MIDI continuous controller information when it detects networks.

Upon discovering this, a small prototype patch was written to turn this information into sound, as seen in Figure 4.1 on page 41. Netstumbler would send out regular pulses of MIDI note information indicating the strengths of the present networks.

The patch simply turned the pulses sent by Netstumbler into notes whose pitches are determined by the network signal strength. The note then has a ring modulator over it whose frequency is randomly changed with every new note. The ring modulator was added to overcome possible monotony of playing notes with the same timbre. This small change provided sufficient to avoid monotony.

Armed with this patch, further cycling trips were tested with laptop in the backpack and the speakers turned up to full volume.

What was experienced was completely different to other wardriving forays. Suddenly the invisible networks could be heard and felt. The backpack would squeak and squawk as the networks were cycled through. It would chirp in high pitches with high signal strength, and rumble in low bass pitches when in the presence of weak networks. The networks were no longer being observed, they were being experienced.

3.3 Warwalking: re

In 2004, the project *re* was started with Alexander Berman. The attempt of the project was to take the live sounds from a city and convert them into music, as a means of recontextualising and interpreting the sounds that are taken for granted and subconsciously filtered from the environment.

The final manifestation of the project strayed from the original concept, which was to employ hijacking of wireless networks and streaming audio to a central server. Due to technical constraints and poor results in the original explorations into the city the project's performances were realised using microphones and cameras directly at the performance venues.

Some preliminary warwalking expeditions through Göteborg were conducted to gauge the feasibility of the project, and potentially find good locations from which to stream the audio. After doing some simple walking and looking at the screen, the *squeak* warcycling patch was eventually applied.

Suddenly the process of discovering networks became much easier. No longer was it necessary to actively scan the screen to discover the networks, but rather listen to whenever the computer was talking. This audification tool was no longer only artistically interesting, but incredibly practical. This was initial proof that there was some merit in the pursuit of sonifying the networks.

But, more astonishingly, was how little needed to be done to achieve a positive result. Up until this point, none of the patch design had been theorised in any form or according to any methods. This provided an encouraging starting point to pursue further development.

4 Project implementation

4.1 Platform choices

The choice of platforms on which the project was built very strongly determine the outcome of the project. Much in the same way that a musician is limited by his instrument, such is the impact of choice of development platforms for the Warbike.

4.1.1 Pure Data

Miller Puckette's (1996) Pure Data ("Pd") is an extremely versatile platform for music and sound development, allowing for rapid development and prototyping.

Pure Data is frequently referred to as "dataflow" programming, named for its visual design similar to data design flow diagrams (Mosoconi 2000), and originated with the MIDI controlling software *Max* (Cycling '74 2005). The intuitiveness of this visual method of programming, as opposed to traditional text based computer programming, and similarity to real-life audio hardware patching, has led to a wealth of similar software packages, especially those working with media. Most notable of these packages are Plogue's (2005) *Bidule* for audio processing, and *Eyesweb* from the University of Genoa's InfoMus Lab (2005) for general media processing with a strong focus on video manipulation and interpretation.

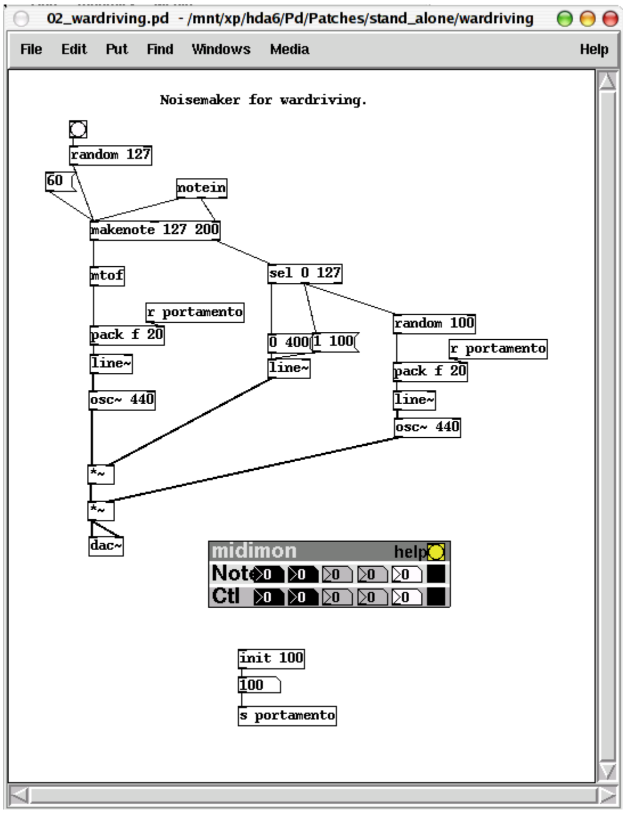

Figure 4.1.: Pure Data patch of the first warcycling experiment

An example of a Pure Data “patch” can be seen in Figure 4.1. This patch is the initial *squeak* programme written as the first proof-of-concept of wireless sonification. The data flows from top to bottom. Each box represents either a function applied to incoming data, or a container for data. The lines joining the boxes dictate the flow of data into and out of the boxes.

Pure Data’s method of working provides for a very rapid development. Unlike most traditional programming languages there is no need to compile source code. The programme’s function is instantaneous.

4.1.2 PDa

Günter Geiger’s (2003) *PDa* is a version of Pd for mobile devices, specifically the Hewlett Packard iPaq and Sharp Zaurus machines. PDa has opened the doors for mobile and portable music creation and performance. Despite its relative youth in the software world, the platform is already quite robust for live performance as both a computing platform and interface.

PDa differs from Pd due to the restrictions of the architecture of mobile devices. Specifically, mobile device processors do not work with floating point numbers. Programmes have to therefore be specifically adapted to work with these processors. Some aspects of Pd have not yet been ported to PDa or perform differently than expected. Because PDa is an open source project maintained by one individual it is always in a state of maintenance, and constantly being updated.

Early experiments with the Warbike had been developed on a laptop. This posed several problems. The first problem was that of size. Laptops are not as portable as their manufacturers would have the consumer believe.

Durability was also a concern. Although I trusted myself to bike with my laptop in my backpack, participants could not be relied upon to be as careful with the Warbike.

The biggest problem when developing the Warbike was that of battery life. It is often true that when all conceptual hurdles can be overcome, the crippling problem is that of battery life. At that time the laptop battery would last for half an hour when it was behaving. If the Warbike were to be on display for any length of time it would have to stay alive longer than that.

4.1.3 Kismet

Previous experiments in warbiking used the popular Windows-based

NetStumbler. Netstumbler was, however, unsuitable for any further experiments. It is extremely limiting, as it is available only for the Windows and WinCE platforms. It is also a stand-alone programme, making access to its information difficult. If the Warbike was to interpret network information, it would require a client/server architecture so that the sound-making component had access to the network information. The amount of information that Netstumbler gathers is also limited. As the power of the tools greatly affects the outcome of the project, it was important to choose as powerful a tool as possible, to allow for deviations in the project's development, should other avenues require exploration.

Mike Kershaw's (2005) open source wireless sniffer, *Kismet*, was the only sensible choice for retrieving and parsing the wireless information. The programme is the de facto tool for wardrivers using Linux. Kismet is able to retrieve all sorts of information from wireless networks, including packet content, should one wish to snoop open networks. It functions as a passive observer of networks, while NetStumbler operates with a broadcast method for discovering networks, making users of the programme visible to network administrators.

A version of Kismet was available for the Familiar Linux distribution for mobile devices, such as the iPaq. The portability of unix-based programmes allows for migration to other platforms in the future, should the project continue in other forms. Choosing Kismet was then a choice not only of power and usability, but also to allow for further growth of this experiment.

Depending on the wireless hardware in use, Kismet can retrieve a wealth of valuable information regarding wireless networks, including the transmitted data of the network itself. It is even smart enough to determine the names of access points that do not broadcast them. The amount of analysis by Kismet truly rivals NetStumbler. NetStumbler functions very well as a wardriving tool, but fails when further information about the networks is required. Previous warbiking experiments with the *squeak* patch were able to use the MIDI output of NetStumbler, but that was as far as that tool could be taken.

What made Kismet particularly appealing was its organisation into client and server architecture. Kismet is purely a server programme with a client included to display the information discovered. What this means is that custom clients can be written to parse and retrieve the data depending on what is required for the given application. For the Warbike, a client would structure the Kismet data in a meaningful way, and then send that data to Pd to create sound.

Kismet provided an extremely powerful tool for which the project possibilities were much greater than before, with NetStumbler.

4.1.4 Python

Python (Python Software Foundation 2005) is a programming language that is quickly gaining acceptance. As an interpreted language it does not require compilation and so, just like Pd, is excellent for rapid development.

Python is an ideal language for beginner or hobby programmers. It has an extremely simple and uncomplicated syntax and handles memory management on its own, freeing the programmer from the worries of memory concerns.

Because it is dependent on an interpreter, which is compiled separately for whatever computing platform is required, it is extremely portable. This enabled development on a laptop that could later be transferred to the iPaq with little or no modification.

4.2 Physical construction

Initial experiments were constructed by placing a laptop in a backpack while cycling, or by walking and holding the laptop. The volume of sound while the computer was in the backpack was not sufficiently loud to fully communicate the sound. Neither did the iPaq (seen with the backpack in Figure 4.2), on which the project was built, have speakers of the volume required to be heard outside of the backpack. A solution was needed for the participant to hear the output of the Warbike programme.

Figure 4.2.: The Warbike backpack, with iPaq outside and in.

The first choice was to use headphones plugged into the iPaq. This appeared to be the ideal method for presenting the sound to the participant. The option of headphones and the types of headphones available provide interesting possibilities in the project.

Headphones act as a barrier between the participant and his environment. Closed-chambered headphones provide a strong sound-barrier against external interference and environmental noise. If the participant is to be thought of in an isolated environment of the wireless infrastructure, the sound of the sonification through the headphones can be thought of as his sensory perception in his navigation through the web.

However, although immersing the participant in the sonification of the networks may seem ideologically pure when representing this communications world, separating the participant from his physical environment removes a large portion of the psychogeographical effects of the experience.

Humans do not perceive their environment solely through visual cues. A large portion of our perception of space comes through the ears. These are not only audio cues about events around us, but ambient information such as ambient noise and pressure, helping us to develop a sense of the shape of the surrounding space and our orientation within it.

The use of open-chambered headphones would provide a compromise between the cocooning effect of the closed-chambered headphones, while allowing the perception of space and events surrounding the participant, preserving psychogeographical awareness of the space.

Ultimately, the decision was made not to use headphones in the implementation of the Warbike. The first showing was at the Artengine residency. Discussions with members of the centre raised the potential liabilities of participants riding on streets with cars, wearing headphones that limited their ability to perceive their environment and protect themselves from potential dangers. While I was personally comfortable cycling with headphones, it was not possible to assume that all participants would be.

The alternative that was selected was to mount speakers on the backpack to project the noise. An audio amplifier was placed inside the backpack. This amplifier could be plugged into the headphone output of the iPaq. Speakers were sewn into the straps of the backpack, in the front of the pack, just over the shoulders, as seen in Figure 4.3. This allowed close placement to the ears of the participant, allowing effective communication of the sound.

Figure 4.3.: Speakers sewn into the backpack's shoulder straps.

The choice of the speakers over the headphones was a compromise between the ideals of the project and the realities of implementing an interactive project. The speakers do provide a certain characteristic of their own that adds to project. They turn the Warbike participant into a sound maker themselves, not merely an isolated listener. The rider becomes an active participant not only of the project, but of the city's soundscape.

4.3 Programming for mobile platforms

Initially the lure of developing the Warbike on a PDA overshadowed any thought of difficulties. A brand of Linux existed for iPaqs, *Familiar Linux* (Familiar Project 2005), a version of Pure Data had been ported to this flavour of Linux, and the popularity and mobility of Wardriving made it probable that Kismet had been ported to this platform as well. iPaqs also purportedly had much longer battery life than laptops, which was the main impetus for using the iPaq over a laptop. It appeared to be a perfect choice.

Günter Geiger's (2003) experience stress testing PDa on the iPaq indicated that the platform would be sufficient for the project. Geiger had tested his iPaq, a weaker model than the 5550 used for the project, with forty oscillators in PDa, and it appeared to function quite aptly.

Computational problems showed themselves much sooner than expected. The power required by other processes performed by the iPaq at the same time had not been taken into account.

While Geiger was most certainly running only PDa, and had probably shut down all unnecessary processes included in the operating system, the Warbike had other processing running concurrently with PDa.

The main process running was Kismet, performing the wireless scanning and analysis. Kismet performs quite a bit of analysis of incoming traffic. As well as Kismet, the Python client was acting as a go-between for Kismet and PDa.

It appeared that Python may not have been the best choice for this task. It may have been better to use a compiled language like C that uses less processing power, than an interpreted language such as Python.

The tasks performed by the Python programme, mostly parsing text from Kismet, are not particularly processor intensive. Regardless, having to perform these tasks does put some strain on the processor.

Because compiled languages like C are translated to machine understandable code, they are much more efficient at executing their tasks. Python has to run with an interpreter that converts the Python code for the machine in real-time. This interpreter consumes processing power that a compiled C programme would not.

All of these processes eventually took their toll on what was possible on the platform. Previous plans for constructing the Warbike programme were scaled back in order to provide a functioning product, while still trying to convey movement through the wireless communications infrastructure. This led to a reassessment of what was necessary to accomplish this in a bare-bones version of the original plans.

4.4 Density mapping

In most traditional sonification experiments the data can be extremely dense, allowing for easy mapping to continuous parameters within the sound or music, such as Bob Sturm's buoy sonification mentioned in Section 2.6 on page 27. The sonification is either of real-time information from continuous, analogue inputs, or traversal of extremely large, multidimensional datasets.

However, the output from Kismet and the wireless networks is not nearly as dense. The information is discrete. Data is sent as chunks when it is received. Information such as new networks detected, status of networks, packets received, and packet information only appear as events within the data, rather than the sampling of a continuous stream. None of the data represent continuous information that forms a smooth path if graphed.

In traditional sonification, changes of state are extremely important. If a user is monitoring her stock on the stock market, she may not care about the absolute value of the stock, rather whether the stock is gaining or losing value.

Because of the discrete nature of the Kismet data, changes in state are not of continuous information. But neither is a continuous change of state nearly that interesting in this situation. Traversal through the wireless network infrastructure in the city can easily be represented by triggering events that represent the presence of a new network.

The structure of music is also quite well suited to this kind of event triggering. Most music is constructed from many singular events, such as notes, chords, and percussion. As such, it is extremely easy to translate the events of new networks, packets, and their corresponding information, directly to musical events such as notes.

4.5 Design theories

The pursuit of the Warbike project is essentially educational. Not all information can be supplied by the experience of using the device itself. Implementation of the project would be supplemented with information so that a participant is aware of what it is that he is hearing, and what this represents. The experience of using the Warbike is what makes this information tangible and understandable. Simply informing an individual about the presence of networks is not enough to make him understand the reality of the pervasiveness of the networks, or the privacy concerns of broadcasting this information into public space.

Implementation of the project would involve the participant either being given text to read, or have explained to them verbally what it is that they are hearing, and why awareness of wireless networks is important.

With the knowledge that the participant is aware of the kind of information that is being used to create the sounds, the scope of the sound design is then narrowed to representing aspects of what the participant already knows.

Essential in the education of the participant is the understanding that most networks are not encrypted. The knowledge that one can gain internet access virtually everywhere in a city is not nearly as interesting as the knowledge that one can obtain passwords and personal information very easily from unwitting users.

To decide how to communicate this information, an analysis of the types of data available from these networks is necessary.

4.6 Data selection

Kismet gives many classes of information about the wireless networks, as well as content sent over those networks. Not all network devices can access all of the classes of data. This provided problems when developing the system on a laptop computer and transferring the programme to the iPaq that either did not receive data that the laptop did, or received useful data that the laptop did not.

Nonetheless, it was necessary to determine which Kismet data was relevant in order to communicate the participant's movement through the infrastructure of networks, as well as determine what qualities and information about these networks were worth representing.

It was also necessary to communicate the activity of the networks. It is important that the participant be aware that these networks are active. Knowledge of the networks' presence generates a strong reaction, but detecting information being sent over the networks generates an "ah ha!" response that truly captures the understanding of being within this communications web.

What information do we communicate to increase the rider's perception of the wireless activity of his area? Which information is irrelevant to this purpose?

4.6.1 Eliminating empty or static data

In order to answer that question, it was important to analyse what data was available from Kismet. Once it was known what was available, decisions could be made to better determine what was and was not valid data to better answer the aims of the project.

The Kismet protocol provides several classes of data:

> NETWORK: information about networks in the current area, and when new networks are discovered
>
> INFO: general information about all the data that Kismet has discovered, such as total number of packets received.
>
> PACKET: information about packets received by Kismet, such as what type of packet it is and its source —a client or an access point.
>
> CLIENT: information about any clients—other computers—in the vicinity, such as type of network card, packets detected, etc.
>
> STRING: if a detected packet is a string of text, Kismet will print the contents of the string (e-mails, instant messenger conversations, passwords).
>
> CARD: what kind of card the Kismet server is using.
>
> ALERT: no information available about this class.

When examining the Kismet data it became obvious that there were differences in the Kismet output depending on the hardware being used. An obvious example of this is the STRING class, which on the laptop hardware, a Texas Instruments ACX111-based card, would display contents of packets, such as web page communications and instant messenger data. On the iPaq, using Orinoco wireless hardware, this class yielded no information.

This proved to be a frustration prior to this data analysis, as early experiments in proof-of-concept programmes written on the laptop would fail on the iPaq, and vice versa. It was not until this data was analysed that it became evident why the programmes were not working.

This inactive data on the iPaq, as well as other data that were not available by the hardware, created fields the produced no output. Empty fields were filtered out of the possible data sources. Examples of these would be the cryptic “lat” and “long” variables in the NETWORK class, presumably for geolocation, however it is uncertain how wireless network hardware could provide that information at all. Those variables were empty, among others, and discarded.

The second criterion for removing variables were those that produced an output, but produced output that was not sufficiently variable to provide any contextual information to the Warbike participant, nor information that could not otherwise be presented through other data.

An example of an unsuitable variable would be the *rangeip* variable in the NETWORK class. After examining the output it was evident that this piece of data was the base IP number that the access point of a specific network would use to assign IP numbers to its clients. An example of the output was “192.168.2.1”, where all clients would be given IPs of the format “192.168.2.X” where “X” is a number from 2-255.

Although the possibilities of this value are quite large, determined by the network administrator, convention limits choices to several options, typically 192.168.0.1, 192.168.1.1, or 192.168.2.1.

This evidently is not sufficiently variable to provide interesting contextual information to the participant. It cannot be mapped to a continuous musical parameter, such as volume. Nor does it provide any information that would not be evident in other pieces of data, such as network information when a new network is discovered by Kismet. The participant would learn nothing of her environment with this information. Nor is the data particularly relevant or useful to the aim of the project.

Most of the information taken from Kismet was similar to the *rangeip* value. It either yielded no information whatsoever, or did not fit the basic criterion of being sufficiently dynamic.

4.6.2 Selecting relevant data

The remaining data had to be chosen that would best accomplish the goal of the project, to communicate the participant's movement through the infrastructure, as well as contextual information that would be relevant.

The most important reason for disregarding data was that it was irrelevant to the aims of the project. For example, the participant would not learn anything valuable by knowing that one particular network had a different *rangeip* than another, as shown previously.

Consider the question that this project is attempting to answer: how can sonification be used to to communicate to a participant his movement through these invisible communications infrastructures?

The first aspect to deal with is the communication of the movement through the structure. If the infrastructure is thought of as a static entity over a city with node points, the network access points, then the participant's movement through this infrastructure will cause him to encounter these new nodes. Knowledge of the presence of these nodes, or discovery of the nodes, allows the participant to establish an internal mental map of the nodes within the physical, urban space of his ride.

The memory of the participant would have to be trusted to construct this mental map. These demands on the participant are not so great. It should be sufficient to have an understand of the immediate neighbourhood and surroundings, and not for him to understand the infrastructure of the entire city, should he bike through it.

If this is the case, that the presence of the networks is enough to establish this mental mapping of the infrastructure, then discovery of new access points and networks, and the representation of these, should be enough to communicate the participant's movement through this infrastructure.

To extract this information, the NETWORK class of data from Kismet must be used. Within this, the most important piece of information is the SSID of the network, the identification number unique to an access point, to identify whether the network is newly discovered or not.

It should be noted that this NETWORK class gives information unique to SSID identifiers of access points, but single networks may have multiple access points. This is especially true of educational and business networks, which tend to cover large areas. The Warbike will be using the messages of this class, sorted by SSID identifier, to signify new networks. This design means that should the participant come across networks with multiple access points they will be notified of each access point as if it were a new network. These large-scale networks are rare, and at most would generate only one or two extra network sounds. This is a trivial condition and is considered acceptable. The participant's experience of the ride will not be affected should they hear the occasional extra network.

Although this does a simple job of determining the basic data for answering the question, it could not possibly do an effective job of making the experience of the networks more visceral and more meaningful to the participant. Just as a picture of an empty highway does not adequately communicate the dangers of automobile accidents.

Since a strong impetus for the creation of this project is the education of not only the proliferation of wireless networks, but the *implications* of these networks, data should be chosen that communicates this as well.

The strongest implication and potential danger of these networks is privacy concerns. Along with this comes the discussion of public space versus private space. The cyclist will be riding around on city streets, in perfectly public space, but have access to the contents of these private networks, the private information of their users.

The ability of the participant to acquire this information depends on one variable of the networks, and that is their encryption statuses. If networks were encrypted, the participant would not have access to the private information of the network users. Thus, communicating the encryption status of the networks is important to convey potential dangers of these open networks.

The encryption status of the networks, just as with the SSID of the networks, is available in the NETWORK class of Kismet data as a binary value of encrypted or not-encrypted.

The last effort that is required to make the experience more meaningful and visceral is to humanise the experience in some manner. While the knowledge of the networks and their encryption statuses helps to establish the movement through the networks, and the contexts of those networks, it does not adequately communicate that the private data is being sent on the networks, at the very moment that the participant is cycling through their influences.

An obvious choice of data for this purpose would be to reveal the contents of the network communications. This would mean e-mails being sent, web pages being accessed, and passwords used. Using this information was impractical for several reasons. The first of which was simply that the iPaq yielded no data in the STRING class of Kismet information, which should show the text contents of the communications.

Choices for not using this data were also determined through other, firm conceptual reasons. The first was that conveying textual data through sound is extremely difficult to do effectively. Short of converting the text to speech—which Kismet can do for access point names—there is no simple way of conveying the content of the text. If the purpose is to create a musical, or musical-sounding output for the Warbike, then speech synthesis is not an option.

The final conceptual reason for not displaying this data is that the purpose of the Warbike is not to actually invade others' privacy, only to communicate that potential invasion is possible. Consider the Warbike to be the equivalent of frosted glass in a shower stall, indicating that someone is showering, without revealing or identifying the bather.

Broadcasting sensitive information entails a breach of privacy not only wrong from a moral standpoint, but most certainly from a legal standpoint. It is not the intention of this project to enter into legal grey areas, merely to educate as to the potential for harm given the current state of wireless network implementations.

Nonetheless, activity of the networks can be communicated without displaying the contents of the activity. The PACKET Kismet data class gave general information about data sent over the networks, such as the source and destination of the packets. Representation of the network packets was enough to convey to the participant that there was activity on the networks in their vicinity.

The PACKET data generated a curious output. One would assume that if the PACKET class represented every packet sent on the networks that thousands would be received per second. The nature of the packets received is actually less.

Each wireless network is assigned to a channel, which is a portion of the electromagnetic spectrum assigned to 802.11 networks. In order for Kismet to be able to discover all possible networks and their data it cycles through the eleven available channels. The result is that while it is searching it will miss data from the other 10 channels. It is possible to assign Kismet to a specific channel, but then only detection of networks on that channel is possible. This channel cycling significantly affects the density of packet information that can be receive from Kismet. But it is believed that the number of packets received during the channel cycling is proportional to the actual number of transmitted packets.

4.6.3 Kismet client

A Python client was written to interface with the Kismet server, receive the useful data, and relay it to Pd in a structure that Pd could interpret with which to make sound.

The original programme used to query Kismet to determine relevant data was used as a basis for the client programme and further modified to query specifically for the useful information, and communicate with Pd through a TCP connection.

Upon connecting to Kismet, the Python client would receive a list of possible data classes available. The client must then inform Kismet that it would like to receive data from a specific class, then specify the items within the class that it would like to receive.

The protocol for communicating with Kismet is of the structure:

```
!#### COMMAND ARGUMENTS
```

where #### is a unique four-digit identifier. The Kismet server will use this identifier to communicate success or failure back to the client of a particular command.

To communicate to the Kismet server that a client would like to receive data from a specific class, in this case the NETWORK class, the client sends the following command:

```
!1000 CAPABILITY NETWORK
```

followed by a command to tell the server that it would like to receive specific data within that class. For the project's purposes this would be the SSID identifier of the access point, and its encryption status:

```
!1001 ENABLE NETWORK ssid, wep
```

The Kismet server will then relay the SSIDs and encryption status of any active networks in its vicinity.

The client performed this operation for several Kismet classes, the NETWORK class; the PACKET class, to know when access points or their clients are sending information; and the INFO class, which gives a general summary of the data that Kismet has uncovered.

4.6.4 Creating an interface protocol

Once the client has begun receiving the data, it is then stored in a Python *class* data type. Classes are custom data types that are particularly useful because of their ability to store any data in any format desired, and perform custom manipulations on the data.

The *networkclass.py* Python class was created to store the information about the surrounding networks. It contained the INFO Kismet class information, as well as information about a number of recently discovered networks. This was initially set to ten networks, assumed to be a good approximation of networks within the current area.

The Python client would pass the Kismet NETWORK information to *networkclass.py*, which would then parse the data into its components. The SSID identifier of the network would be compared to those of the existing ten networks. If the network had been seen previously, the data was ignored but the time that the network was last seen was noted. If it was a new network, the oldest network stored in *networkclass.py* would be replaced by the new network's information.

The information gathered from *networkclass.py* then presents several salient data. The first is the discovery of new networks, which can then be communicated to the participant. The second is the encryption status of the network. The third is the percentage of encrypted networks in the immediate area.

4.7 Sound design

The sound design for the Warbike has three components, to reflect the three classes of information. The first represents the presence of new networks, the second is the packet information, the third is an ambient sound representing the ratio of encrypted networks in the vicinity.

A simple two-oscillator frequency-modulation (FM) synthesiser (Chowning 1973) was created in Pd to provide the sound generation. The decision was made to use synthesis instead of sample playback because the possibilities for alteration of the sound are much simpler to execute using synthesis parameters than determining what kinds of effects are necessary to create unique sounds from a small sample base. At the root of the decision was the need to take into account the small memory space on the iPaq, as well as the processing power needed for sample playback.

FM synthesis was chosen primarily because of its relative simplicity to construct, while still yielding a broad range of complex timbres. Because it is simple to construct, it is also computationally efficient.

The sound design process went through two major stages. The first was shown at the Artengine residency, to good response. The result, however, did not accurately reflect my intentions with the project and required significant redesign. The Warbike's sonification was then redesigned for a talk and demonstration at the Big Love gallery in Göteborg, Sweden in November of 2005.

4.7.1 Artengine design

Initially the design was to assign a separate synthesiser to each network in the immediate area, where each network would play a unique sound with a unique pan placement. It very quickly became apparent that the processor of the iPaq was not able to perform adequately, as several active synthesisers caused the machine to become unresponsive. The decision was then made to use only two synthesisers playing packet information, each synthesiser was panned left and right, with different timbral settings. Networks and their packets were arbitrarily assigned to either the left or right synthesiser.

When packet information was received, the Warbike played a random note, within a three-octave range, per packet received, on the synthesiser to which the packet's network was assigned. The packet synthesisers were given sounds with long decays, very characteristic of the FM "bell" sound.

Upon testing this packet sonification it sounded as though the Warbike was a set of wind chimes, and the packets were wind blowing through the chimes. When the stream of packets passed through the Warbike, it triggered a trickle of notes, a random melody.

Early experiments with the synthesiser caused problems with too high a packet density. At its most minor, the synthesisers created digital clicks when they were triggered too quickly. At its most major, a high density of packets caused Pd to crash. The packet information was then filtered to allow only one packet to trigger a synthesiser every 100 ms. This was determined to solve those problems, and function nicely with the bell sounds of the packet synthesisers.

When a new network was discovered, a random note was also triggered. Initial experiments revealed that a method was needed to differentiate the packet information from the network discovery. Although each system had different sound qualities based on the synthesiser settings, it was found to be insufficient to make them unique and distinguishable from each other.

To separate the two processes, the new network notes were played in a much higher register than the packet information. The result was shrill, piercing sounds for the network discovery, with lower, softer sounds for the packet information.

Packet sounds help to remind the participant that there is activity in the neighbourhood, while the discovery of a new network is what generates the “ah ha!” moment of discovering information about a neighbourhood. The shrill sounds of the higher register did a better job of grabbing the participant’s attention, while the lower packet information provided a subtle background layer.

To distinguish between new networks’ encryption statuses, a form of distortion was needed. Open networks would be played distorted, while closed networks would sound cleanly.

This may seem counter intuitive, as encrypted network data appears as garbage unless a user has the key. However, if the ideology of this project and the educational objective for the participant are of the tone that open networks are bad because of their privacy concerns, then it is those open networks that should sound unpleasant, while the closed networks should sound pleasant and comforting, reinforcing the safety of encryption.

Initially a wave shaper was written in Pd to provide the distortion. The amount of deviation from the original wave shape was determined by a gaussian spread whose deviation could be altered to distort the noise more or less depending on qualities of the network. The input sample’s value would be offset by the gaussian value.

At this point processing limitations were encountered. The intensive

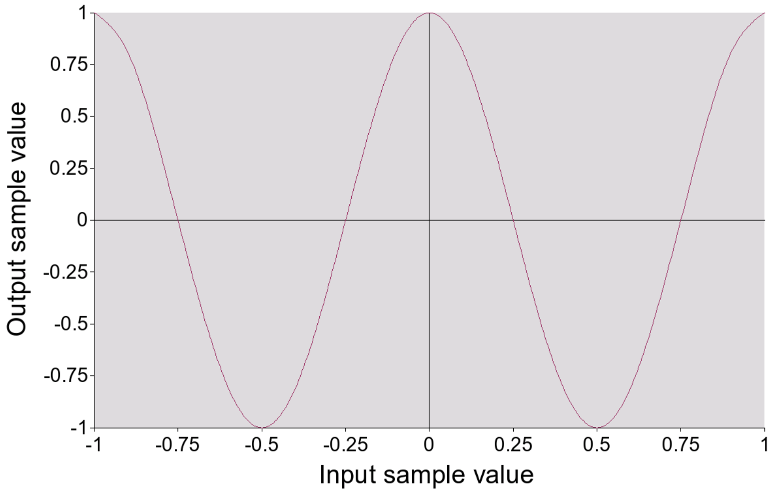

Figure 4.4.: cosine distortion input/output graph

wave shaping patch needed to be removed or redesigned to be less strenuous on the processor. The patch was replaced with a simple *cosine* mapping to the incoming signal using one of Pd's standard objects, an interpolated cosine lookup table. The input/output sample mapping of the cosine distortion can be seen in Figure 4.4. The input sample values are transformed through a cosine function of two periods over the input sample range of *-1* to *1*. This distortion significantly lowered the amount of CPU required to perform the function compared with the gaussian process.

New encrypted networks played a random note in a register several octaves above the packet information. New unencrypted networks played random notes in the same register, but distorted with the cosine function.

The final piece of information to be represented was the percentage of encrypted networks in the vicinity. Whenever a new network was discovered, the Python client would calculate the ratio of networks and pass that to Pd.

Pd played a constant low pulse that was initially run through the gaussian wave shaper mentioned previously. The wave shaper was abandoned for the use of the other synthesisers because it was determined to be too processor intensive to be useful several times with several synthesis units. However, using it only once on the pulse functioned adequately.

This low sound provided a constant drone-like pulse under the texture of the packet and new network information. The amount of wave shaping distortion applied to the drone sound was determined by the ratio of encrypted networks. The more unencrypted networks there were, the more distorted the sound was. The motivation behind this was the same as was followed when deciding which new networks would be distorted: encrypted is good, unencrypted is bad.

Testing the Warbike backpack at Artengine with participants led to some excellent unforeseen results. Because the speakers were sewn into the shoulders of the backpack, the participants could feel much of the bass sound in their shoulders. The low drone representing the amount of encrypted neighbouring networks translated strongly through this physical communication.

This result created a re-interpretation of how to properly communicate the low drone, and how to exploit the physical side-effects of the speaker placement.

A treatment was needed for the drone that would yield a tactile response and still be able to communicate the same information as previously with the distortion.

An amplitude modulator at low frequencies was chosen to replace the gaussian distortion. The frequency of the modulator varied between *0-10 Hz*, resulting in relatively long periods. The result of this is that for predominantly encrypted areas, the drone would slowly fade in an out, very subtly, with a frequency close to *0 Hz*. At highly unencrypted areas the drone would rumble, with the modulator close to *10 Hz*.

The result of this modulator was extremely tactile, allowing the participants to feel the speakers pulse on their shoulders. Ultimately, it created a much more effective sonification of the information, contributing to the overall experience of the backpack.

4.7.2 Big Love Design

The Artengine design produced many excellent results, but further considerations found it deficient in several areas. These deficiencies prevented the device from fully accomplishing its desired task of educating the participants of the presence of encrypted and unencrypted networks.

The first issue was that the low drone sound became unnoticeable and occasionally masked by the packet sounds. The packet bell sounds frequently had very low frequencies and these would interfere with the drone sounds. To compensate for this, higher frequencies were added to the timbre of the drone to make it distinguishable as a separate entity.

To create higher frequencies it was affected by the same cosine distortion shown in Figure 4.4. This provided a little more shape to the sound. In order to add more high frequencies, the signal was also digitally clipped, creating a digital distortion. An example of the affect of the clipping on a waveform can be seen in Figure 4.5. These processes allowed the low drone to still maintain its low rumbling sound, but be distinguishable from the other sounds by its higher frequencies.

The following two issues involved both the packet and new network sounds, and the solutions taken solved both problems. The first problem was that the new network and packet sounds were occasionally indistinguishable from each other. The higher range of the packets was close to the lower range of the new networks sounds. Both sounds also had very similar bell-like timbres and exponential amplitude decay, making them difficult to differentiate.

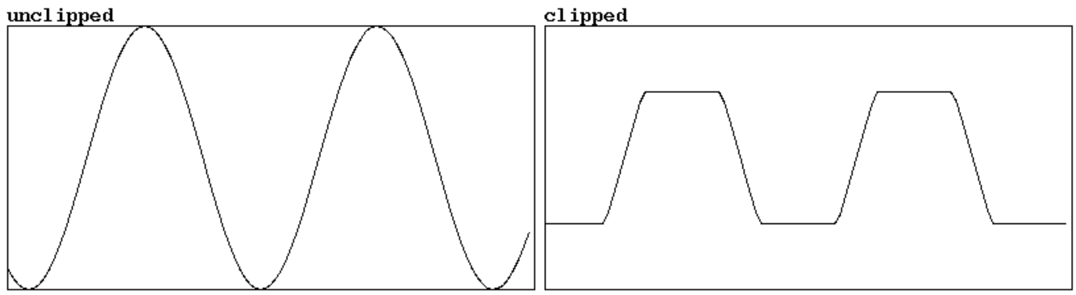

Figure 4.5.: An example of a waveform before and after digital clipping.

The second problem was that the encrypted new network sounds were occasionally difficult to differentiate from the unencrypted new network sounds. The distortion applied to the synthesisers for the unencrypted networks was insufficient in changing the character of the sound. Because the register of the sounds was so high, the distortion was frequently unheard because of the small number of partials within the audible spectrum.

Because it did not matter what register the packet sounds were in, and the network sounds could not function in the higher register, the registers of the network and packet sounds were switched. The network sounds were then played in a medium register, while the packet sounds were played in the upper register.

The distortion of the network sounds was then more audible in the middle register. There was more room for the distortion's partials between the fundamental frequency of the synthesiser and the upper-end of human hearing. In order to make the distortion more evident, a more severe digital clipping than that applied to the drone was applied. The distorted, unencrypted networks now sound quite "dirty," while the encrypted networks sound very pure. No longer could they be confused for each other.

In the Artengine design, both of the network and packet synthesisers had very bell-like sounds. They had a sharp attack with a very long decay. To further differentiate the packet from network sounds, the packets were given a much shorter decay. Their sound was then closer to that of drops of water than bells.

The final result of the sonification was a backpack that would play calm bell-like sounds when discovering new, encrypted networks, and harsh, dirty bells when discovering unencrypted networks. Little water drop type sounds were heard when packets were discovered, communicating the activity of computers, and most likely people, on those networks. And it would hum and rumble based on the perceived safety of an area, based on the ratio of encrypted and unencrypted networks, communicating the potential dangers or opportunity for intrusion in the neighbourhood.

5 Discussion, Conclusions

5.1 Conclusion

The purpose of the Warbike was to use sonification to investigate how to communicate to a cycling participant his movement through the communications infrastructure of wireless networks.

Through the sonification of the packets, and the presence and quality of new networks, the participants were able to develop an understanding of the proliferation and presence of the wireless grid over the city, and the activity of the users of the network. The packet sonification especially communicated the idea espoused in the Doctorow quote on page 4, of the life and activity coursing invisibly through our neighbourhoods.

The communication of the qualities of the networks, specifically the encryption status, helped the participant develop an understanding of the potential for intrusion. The participants developed an appreciation for the state of security of neighbourhoods and technologies that previously seemed harmless or benign.

The Warbike also communicated the ideologies espoused by psychogeography, although this was not difficult. Even the early experiment warbiking with the *squeak* programme embodied a psychogeographical experience without attempting to do so.

The Warbike functioned excellently once completed. Observing participants wearing the backpack at both the Artengine exhibition and Big Love talk illustrated why the project's aim was justified. It was possible to see a flicker of understanding in their eyes and expressions. It was evident that they were perceiving their environment in a different manner, a more educated and understanding manner. Conversations with them afterwards were full of many questions, further enquiring about the specifics of what it was that they heard. The Warbike served to create an interesting dialogue around all the key issues it was attempting to address—network security and privacy, and psychogeography and neighbourhood awareness.

5.2 Discussion

This final product is, however, a prototype, and has room for much improvement. Personal experience using the device, and the experience of others, has highlighted problems in the construction, both conceptual and practical.

The practical issues are the simplest to discuss, because their solutions are relatively straightforward, whereas the conceptual issues require a little more thought, with many more possible solutions.

The initial physical construction of the backpack provided some issues with volume. Because the speakers were chosen instead of headphones, the problem of sound volume had to be addressed. In the current construction, the speakers and amplifier were a pair of battery-powered computer speakers. They were not sufficiently loud to be adequately heard over the din of the city. A stronger amplifier should be sufficient to solve this problem—or lobby to decrease the number of cars on city streets.

There were also other sonification avenues that could have been explored but were not. Other options could have been chosen for the packet sonification. Unique or generative melodies could have been chosen, rather than random. Unique melodies would have created the problem of dealing with monotony in the pattern, as the appeal of repeated melodies would fade quickly. Unless the concurrent melodies were extremely differentiable from each other, it may be difficult for the participant to distinguish between them. Generative melodies might have created an interesting design problem, but most likely would not have brought anything relevant to the project.

Discussions of the synthesis and melodies do not touch the possibilities of not using synthesis as the basis for the sonification but using samples. Samples were initially avoided because the treatment of samples is a much trickier task, heavily dependent on the choice of the initial samples.

Although synthesis is also a wide field with many options to explore, it has created several comfortable paradigms, such as FM synthesis, which are well-understood and could be simply modified to suit the needs of project.

The use of samples also presents the further complication of psychological associations with the sample material. This would be a fascinating field to explore, using specific samples to either reinforce the experience of the wireless networks, or potentially subvert the experience through the use of unexpected samples. The choice of synthesis provided a simple, acousmatic tool set with which to work. That is, a tool set devoid of the potential psychological associations that samples might contain.

Ideologically there are issues that require addressing. If the objective was to educate the participants about the potential harms to privacy, this could have been addressed in more concrete ways. Would exposing sensitive data, such as passwords, have been more effective? Text-to-speech of passwords would have been a very stark tool for displaying the realities of open networks. However this would call into discussion issues of privacy, ethics, and legal ramifications that would distract from, and not contribute to the project's main goal of being an educational tool and experience.

If this path were followed, sonification would no longer be the focus of the thesis. Sonification was chosen as the medium within which to work, complete with its limitations. Deviation from the medium may have compromised the structure of the project.

The objective of the project was to educate through an experience. The experiential communication, as was argued earlier, is stronger in conveying ideas than merely knowledge. Text-to-speech would not have given that same experience.

One of implications of using sonification is that the user must be informed of what the sonification represents. Would it not have been better to construct a system that is intuitive and requires no explanation on the part of the creator?

Explaining the sonification produced a side benefit, in that it encouraged a discourse between myself and the participants. Before and after use of the Warbike, it provided an opportunity to discuss the issues and experience of the project. If the Warbike provides a experiential understanding of the state of security of wireless networks, the post-ride discussion will give them a deeper understanding of what is at stake.

Further development and additions to the code of the project may also not have been possible. The limitations of the processor were already reached while trying to accomplish simple tasks in the sonification. Adding text-to-speech and other processes may simply not have been possible.

There exists much room for improvement and exploration in this experiment. Perhaps the project will be relevant until such time as the general state of security of wireless networks catches up to the desires of the public, or until the awareness of the public catches up to the failings of the technology. But until that time comes, this pursuit and education will continue to be necessary.

6 References

Augé, Marc. (2005) *Non-places: Introduction to an Anthropology of Supermodernity.* Verso Books, London.

BBC. (2004) Wireless web gets a set of wheels. *news.bbc.co.uk.* <*http://news.bbc.co.uk/1/hi/technology/3726347.stm*> Last accessed November 15, 2005.
The original *magicbike.net* site is no longer active. Old content is accessible through the Wayback Machine: <http://web.archive.org/web/*/http://magicbike.net>

Benjamin, Walter. (1986) Paris, capital of the nineteenth century. In Demetz, Peter. (ed.) *Reflections: Essays, Aphorisms, Autobiographical Writings*. Schoken Books, New York.

Bluejay, M. (2005) *Inappropriate police response to Critical Mass rides worldwide*. <http://critical-mass.info/police.html> Last accessed November 15, 2005.

Bruckner-Cohen, Jonah. (2003) *WiFi Hog*. <http://www.mee.tcd.ie/~bruckerj/projects/wifihog.html> Last accessed November 15, 2005.

Chandler, Annemarie. (2004) Mobile Fictions, Interactivity and the Social Re-configuration of Public Space. In *Proceedings of Interaction: Systems, Practice & Theory,* Sydney, November 16-19 2004, Creativity and Cognition Press, Broadway, 211-270.

Cherubini, M., Nova, N. (2004) To Live or To Master the city: the citizen dilemma. *Imago Urbis* (2), April. Universitas de Quilmes, Buenos Aires, Argentina.

Cheung, Humphrey. (2005) The Feds can own your WLAN too. *Tom's Networking*. <http://www.tomsnetworking.com/Sections-print-article111.php> Last accessed November 15, 2005.

Chowning, J. 1973. The synthesis of complex audio spectra by means of frequency modulation. *Journal of the Audio Engineering Society* **21**(7): 526-534.

Critical Mass. (2005) *www.critical-mass.org*. <http://www.critical-mass.org> Accesssed November 15, 2005.

Cycling '74. (2005) *Max/MSP*. <http://cycling74.com/products/maxmsp.html> Last accessed November 22, 2005.

Debord, Guy. (1958) Theory of Dérive, Internationale Situationniste #2. In Knabb, K. (ed.) *Situationist International Anthology.*

Debord, Guy. (1967) *La société du spectacle*. Buchet-Chastel, Paris; (1994) *The Society of the Spectacle*, Knabb, Ken. (trans.) Zone Books, New York.

Doctorow, Cory. (2005) *Someone Comes to Town, Someone Leaves Town.* Tor Books, New York.

Erickson, T. (1993) From Interface to Interplace. In *Proceedings of Conference on Spatial Information Theory,* Marciana Marina, Italy, September 19-22, 1993, Springer-Verlag, Heidelberg, 391-405.

Etter, R., Grathwohl, D. (2005) *Awarecuffs*. <http://www.richardetter.net/awarecuffs.php> Last accessed November 15, 2005.

Familiar Project. (2005) *The Familiar Project*. <http://familiar.handhelds.org> Accessed November 20, 2005.

Flanagan, Mary. (2005) Understanding New Media. <http://www.maryflanagan.com/courses/2005/UNMs05/unmSp05-2.pdf> Last accessed November 15, 2005.

Gaye, L., Mazé, R., Holmquist, L-E. (2003) Sonic City: The Urban Environment as a Musical Interface. In *2003 Conference on New Interfaces for Musical Expression,* Montréal, 109-114

Geiger, Günter. (2003) PDa: Real Time Signal Processing and Sound Generation on Handheld Devices. In proceedings of *International Computer Music Conference*, Singapore, September 29 – October 4, 2003.

Gutwin, C., Greenberg, S. (1999) *A framework of awareness for small groups in shared-workspace groupware*. Technical report 99-1. University of Saskatchewan, Saskatoon, Canada.

Haglund, M., Schneider, S. (2004) *Den nakna staden*. Glänta produktion, Göteborg.

Hewitt, Darsha. (2005) Personal correspondence with the artist.

InfoMus Lab. (2005) *The EyesWeb Project*. <http://www.eyesweb.org> Last accessed November 22, 2005.

International Telecommunication Union. (2003) *Yearbook of Statistics*. L'Union, Geneva.

Jacobs, Jane. (1961) *The Death and Life of Great American Cities*. Vintage, New York.

Jordan, John. (1998) The art of necessity: the subversive imagination of anti-road protest and reclaim the streets. In McKay, G. (ed.) *DiY Culture: Party and Protest in Nineties Britain*. Verso, London.

Kanpur-Lucknow Lab. (2003) *KLL: Activities: Infothela*. <http://www.iitk.ac.in/MLAsia/infothela.htm> Last accessed November 15, 2005.

Kershaw, Mike. (2005) *Kismet*. <www.kismetwireless.net> Last accessed November 15, 2005.

Kinberg, Joshua. (2004) *Bikes Against Bush*. <http://www.bikesagainstbush.com> Last accessed November 15, 200

Kramer, G., Walker, B., Bonebright, T., Cook, P., Flowers, J., Miner, N.; Neuhoff, J., Bargar, R., Barrass, S., Berger, J., Evreinov, G., Fitch, W., Gröhn, M., Handel, S., Kaper, H., Levkowitz, H., Lodha, S., Shinn-Cunningham, B., Simoni, M., Tipei, S. (1999) *The Sonification Report: Status of the Field and Research Agenda.* Report prepared for the National Science Foundation by members of the International Community for Auditory Display. ICAD, Santa Fe.

Lane, Giles. (2004) Social Tapestries: Public Authoring and Civil Society. *Proboscis Cultural Snapshots* **9**, July.

Lee, Karen. (2004) *Hotspot Bloom*. <http://www.hotspotbloom.com/> Last accessed November 15, 2005.

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

McCullagh, Declan. (2005) Unsecured Wi-Fi would be outlawed by N.Y. County. *news.com*. <http://news.com.com/2102-7351_3-5934194.html?tag=st.util.print> Last accessed November 15, 2005.

Merabet, L., Rizzo, J., Amedi, A., Somers, D., Pascual-Leone, A. (2005) Opinion: What blindness can tell us about seeing again: merging neuroplasticity and neuroprostheses. *Nature Reviews Neuroscience* **6**, 71-77.

MIDI Manufacturers Association. (2005) <http://www.midi.org> Last accessed November 15, 2005.

Milgram, S., Jodelet, D. (1976) Psychological Maps of Paris. In Proshansky, H., Ittelson, W., Rivlin, L. (eds.) *Environmental Psychology: People and Their Physical Settings.* Holt Rinehart and Wilson, New York.

Milner, Marcus. (2005) Netsumbler. <http://www.stumbler.net/> Last accessed November 15, 2005.

Mosconi, M. Porta, M. (2000) Iteration constructs in data-flow visual programming languages. *Computer Languages* **26**(2), 67-104.

Ness, Susan. (199) Opening statement, spectrum management en banc hearing," *FCC*. April 6, 1999. <http://www.fcc.gov/enbanc/040699/tr040699.pdf> Last accessed November 23, 2005.

Rizzo, Frank. (2005) Perspective: Philadelphia's big dig. *news.com*. <http://news.com.com/Philadelphias+Big+Dig/2010-1071_3-5579848.html> Last accessed November 15, 2005.

Nova, Nicolas. (2004) *Locative Media: a Literature Review*. CRAFT Internal Report 2. École Polytechnique Fédérale de Lausanne, Centre de Recherche et d'Appui pour la Formation et ses Technologies, Lausanne, Switzerland. <http://craftsrv1.epfl.ch/MT/research/archives/CRAFT_report2.pdf> Last accessed November 15, 2005.

NYC Wireless. (2005) *NYCWireless.* <http://www.nycwireless.net> Last accessed November 15, 2005.

Paul, Christiane. (2003) *Digital Art*. Thames & Hudson, London.

Plant, Sadie. (1992) *The Most Radical Gesture: The Situationist International in a Postmodern Age*. Routledge, London.

Plogue. (2005) *Bidule*. <http://www.plogue.com/index.php?option=content&task=view&id=21&Itemid=35> Last accessed November 22, 2005.

Puckette, Miller. (1996) Pure Data: another integrated computer music environment. In Proceedings of the *Second Intercollege Computer Music Concerts*. Tachikawa, Japan, 1996, 37-41.

Python Software Foundation. (2005) *Python Programming Language*. <http://www.python.org> Last accessed November 20, 2005.

Romaine, M., Roper, A., Walters, Jeff. (2001) *MIDI Bike*. <http://www-ccrma.stanford.edu/~anrew/250a/bike/> Last accessed november 15, 2005.

Schott, John. (2004) Magic bike: Yuri Gitman's mobile wireless Hotspot. *Ratchet Up*. <http://www.ratchetup.com/eyes/2004/08/font_colorff000_1.html> Last accessed November 15, 2005.

Shields, Rob. (1994) Fancy footwork: Walter Benjamin's notes on *flânerie.* In Tester, K. (ed.) *The Flâneur.* Routledge, London. 1994.

Sturm, Bob L. (2002) Surf Music: Sonification of Ocean Buoy Spectral Data. In *Proceedings of the 8th International Conference for Auditory Display*, Kyoto, July 2-5, 2002.

Slashdot. (2002) *Toronto, the Naked City*. <http://slashdot.org/article.pl?sid=02/09/10/1655200> Last accessed November 10, 2005.
The original *nakedwireless.ca* site is no longer active. Old content is available through the Wayback Machine: <http://web.archive.org/web/*/http://nakedwireless.ca>

Statistics Canada. (2005) *Selected dwelling characteristics and household equipment*. <http://www40.statcan.ca/l01/cst01/famil09c.htm> Last accessed November 15, 2005.

Trachtenberg, Marvin. (2001) Architecture and Music Reunited: A New Reading of Dufay's Nuper Rosarum Flares and the Cathedral of Florence. *Renaissance Quarterly* **54**(3), 741.

Shimomura, T., Marko, J. (1996) *Takedown: The Pursuit and Capture of Kevin Mitnick, America's Most Wanted Computer Outlaw-By the Man Who Did It*. Hyperion Books, New York.

Tuters, Mark. (2004) The Locative Commons: Situating Location-Based Media in Urban Public Space. *Futuresonic 04 proceedings*, Manchester, April 27th - May 2nd 2004.

University of Warwick. (2004) *Tunable Windows To Keep Office Secrets*. Press release. <http://www2.warwick.ac.uk/newsandevents/pressreleases/NE1000000098249/> Last accessed November 15, 2005.

Warren, Charles W. (1973) Brunelleschi's dome and Dufay's motet. *Musical Quarterly* **59**, 92-105.

Westerkamp, Hildegard. (1974) Soundwalking. *Sound Heritage* **3**(4), 18-27.

Wickens, C. D., Gordon, S. E., & Liu, Y. (1998) *An introduction to human factors engineering*. Addison Wesley, New York.

Wi-Fi Alliance. (2005) <http://wi-fi.org> Last accessed November 15, 2005.

WiFisense. (2003) *WiFisense.* <http://wifisense.com> Last accessed November 23, 2005.

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