Doctoral Thesis

Liminal Space

Towards New Paradigm of Urban Computing

by

Jan Rod

Submitted to the Graduate School of Media Design
in partial fulfillment of the requirements for the degree of

DOCTOR OF MEDIA DESIGN

at the

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Abstract

Liminal Space is a design concept of urban space where technology enters symmetric relationship with people and environment. In Liminal Space, technology is promoted and invited to improve experience with the urban space through connecting the missing links between different scales of places from human body, through a building, neighbourhood to the whole city.

Within this dissertation, I explore the concept of Liminal Space both from theoretical as well as practical sides, as theories often develop hand in hand with practical design research. The theoretical approach is founded in "Actor-network theory" (ANT) that redefines the relationship between people and other entities and the environment they share. Using ANT to promote technology to an egalitarian status with humans, however, is only a first step.

Within urban media design research we presently identify to main streams of approaches: "companion technologies" and "situated technologies". Liminal space brings together companion technologies in the form of by embedded interfaces residing close to our bodies and connecting them with data extracted from space by situated technologies.

Navinko is a digital artefact designed to demonstrate the liminal space experience and uses aural interface to generate music based on shared locations of interest. It re-purposes the information created for sharing on screens turning urban landscape of Tokyo into generated musical experience based around users' movement and situation context.

Keywords: embedded user interfaces, ubiquitous computing, urban landscape, city, urban computing, design theory, philosophy, agency

Thesis Advisor: Naohito Okude
Thesis Co-Advisor: Masa Inakage

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"To strive, to seek, to find, and not to yield".

Alfred Tennyson

Disclaimer

I hereby declare that this dissertation is my own original work and has not been submitted before to any institution for assessment purposes.

Further, I have acknowledged all sources used and have cited these in the reference section.

Jan Rod

Part I

Thesis

Chapter 1

Introduction

1.1 Navinko in Liminal Space

The liminal space is a vision of the city where the exchange of meaning between various human and non-human actants brings a radical change. It creates environment where people inhabiting the city are stimulated towards action by the active space, not only passively moved by the physical urban design. Liminal spaces are environments, where agency of the non-human is acknowledged as positive, catalyzing power that transforms the space. They actively taking part in circulation of meanings, they are designed to be aware and enrich the experiences of their users through various companion devices.

Navinko, an iPhone application and a design artifact of liminal space creates the experience with music generated from Foursquare data, locations in space acquired through GPS. User feels like every move she makes make the environment orchestrate a different composition. The sounds are coming from visible and invisible places around and stimulate user to go and explore what is around her. Navinko brings the experience with liminal space that is built by combination of ubiquitous sensing technology spread in space and stimulative personal interfaces that transform these data into nudges.

One can think smartphone or any other mobile device that is close to our body as a "companion technology". The "situated technologies" that can extract data from space, either via Near Field Communication, Bluetooth,

Figure 1.1: View on Shibuya Crossing. Photo by author.

Xbee or internet then work with the companion technology to stimulate the user to take action. Besides exploring the city and stimulating users to walk in the certain directions or take certain paths, in liminal space the technology can motivate people to smile before it lets them out of their home on the street, it can emphasize the need of walking for healthy lifestyle by giving users discounts to restaurants if the refrain from taking a train.

Human and a computer are much closer in liminal space. Technology has power to influence users by living close to their bodies. It taps into their senses, it takes advantage of people being accustomed to listen to music through headphones while walking in the city for a few decades already. Other interfaces like that can be built around vibrations, to stimulate touch, or our peripheral vision, such as physical objects changing colors, or maybe even smell.

Navinko interfaces with large amount of situated data from Foursquare,

which has a large database accessible through open API. Navinko system downloads this database of locations. Because it is a large amount of data, it is filtered by certain criteria to be suitable for the program that generates the music. For example, if there is a duplicate database entry on one location by two users, it would duplicate the sound played and confuse user.

There are many other types of data suitable for designing the liminal space besides locations. These data can come from small, local projects, sensor networks or installations. The most important feature is that they are open and accessible through APIs. They can be the reused and put into different, stimulative contexts using different interfaces than intended.

The liminal space is a vision where companion mobile technology is combined with situated embedded ubiquitous computing applications. In this vision, the outcome is a strong focus on context of the situation and location, while user is stimulated to take action. The active and stimulating technology in liminal space has agency (Latour, 2005). Agency here means an ability to act, to perform action that has some influence over the other actant (Law, 1986). Actant can be a human user, device, sensor network, bicycle or, in largest sense the environment itself. In Navinko the mobile phone, a type of companion device, generates music that influences our movement through headphones that we wear all the time, unlike looking at the device screen. Similarly, it could influence other areas of our decision making than just walking around.

The concept of agency and actants are described by Michael Callon's and Bruno Latour's Actor-network theory, or ANT, (Callon, 1986; Latour, 1979, 2005; Law, 1986, 1992) that tries to explain the way elements that surround us influence each other. Agency, the ability to act is attributed to every actant. When I listen to Navinko app, the iPhone is an actant, and it influences the user. User moves around too, as it is also an actant, and

influences the music generated within Navinko.

We are, in fact, already quite used to the idea of non-human agency and actants, that stimulate us on the daily mundane basis. Take the alarm clock. Every night, we set the time and then completely surrender ourselves in the sleep to the machine itself, with the experience trained by hundreds of successful wake-ups over the last few decades. Contemporary alarm clocks (see figure 1.2) are not even the mechanical machines some probably still remember. They are pieces of software, ported and running on handheld smartphones, being related to those mechanical ones only by a name.

The alarm clock is an example of technology archetype that we believe in and that underwent significant transformation from a device to a code, software, that runs on many devices. Beyond this rather philosophical explanation, we can see that the agency and exchange of it is represented by data. While I walk around, my agency stimulates the GPS chip in my iPhone and that action, walking, is translated into the data. These data are than transmitted to the server, where they are stored in the database. Navinko then uses these data to calculate mutual positions of other locations and synthesizes them into the music. This perpetual cycle of mutual influence demonstrates the concept of agency as well as another important concept, the symmetry of actants.

The users that generate data and Navinko system are, from the theoretical point of view, equal. As actants, they mutually influence each other. While Navinko represents locations as parts of music, it is in a much larger scale than the user herself. It is important though, that it connects these scales, one on the level of the neighborhood or a city, and the second one on the intimate level of the body, the earphones in users ears that play the music. In such arrangement McCulloughs scales are becoming actants (McCullough, 2005). It is not a user in an environment, but rather than that it is a user

Figure 1.2: Westinghouse electric, mechanical alarm clock (1), agency outsourced to mechanical system connected to electrical grid. Digital electronic alarm clock (2), agency outsourced to digital, often radio-controlled system. iPhone alarm clock (3) with familiar setting, but running as software feature, agency outsourced to companion device with universal capabilities. Source: Wikipedia

and an environment. The companion handheld device augments the user and is both interfaces and a senses , such as Navinkos headphone interface and GPS logging.

In practice, and especially during ethnographic research, it is important to approach actants from the point of view of agnosticism. To be agnostic means to suspend any previous knowledge we might have about the subject. ANT teaches us that in ethnography the actants must be approached impartially and all granted with the same terminology and theoretical terms that describe them. For instance, while we might approach Navinko as an application, a piece of software, as purely technical actant, it is also social, as it was created by students of KMD and various factors, such as advisory of professors and fellow colleagues, helped to shape it.

Navinko user, bicycle, city of Tokyo, Foursquare servers, iPhone: all these are actants in Navinko (see fig 1.3). They all participate of the formation of the experience and thus can be then seen as symmetric. They have different degrees of complexity, nevertheless all are equally needed to constitute the full experience as it was designed.

The data and its accessibility is very important for liminal spaces. If there was no Foursquare with open API, we would not be able to access everyones favorite places around Shibuya and Navinko would probably not exist. At the same time, the data that Navinko produces, such as walking patterns, are open and can be later used to connect like joints to other services or applications.

This dissertation proposes to design liminal space by joining together mobile companion technology that has an ability to stimulate and sense users, together with situated technologies that are tailored to the actual place that they are embedded in. The handheld device will then becomes a tool

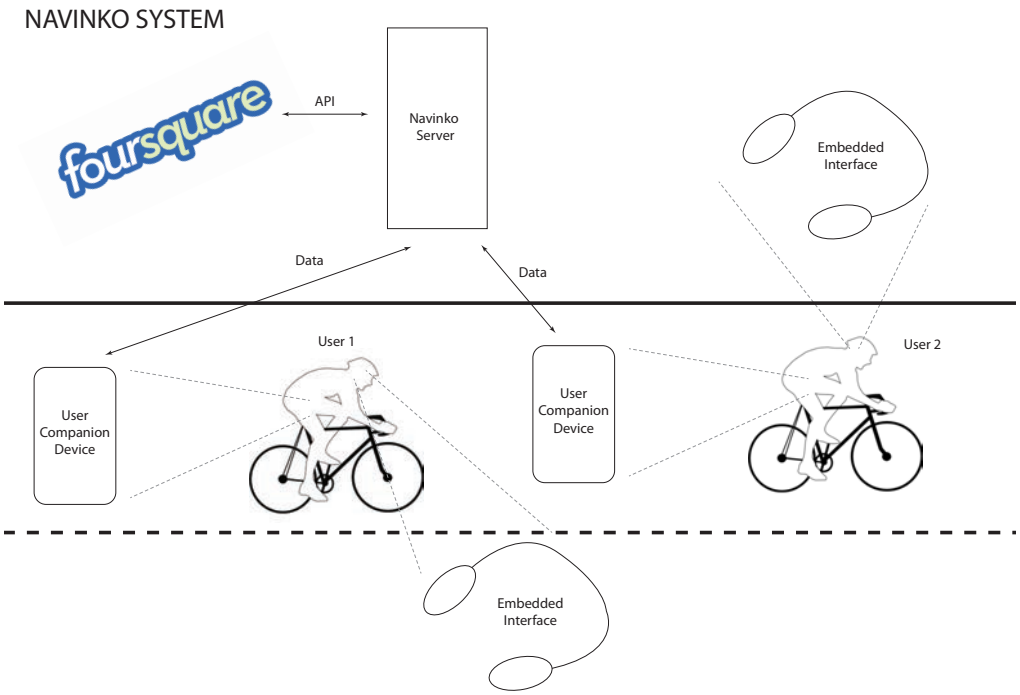

Figure 1.3: Navinko scheme visualizing the basic data flows and configuration of the system. Created by author.

to both stimulate users with innovative interfaces, but also to gather about them and allow them act.

Navinko is a design artifact of liminal space envisioned to allow users to experience the liminal space. It focuses on the interaction to be entertaining and stimulating. It also emphasizes the design of the innovative nudges that are still related to metaphors we are familiar with. Navinko uses simple sound positioning and volume control based on the direction vector and distance of the user and the location that creates part of the music. While user passes the location, the system synthesizes doppler effect, that helps to determine the exact position and moment of passing.

Two larger scale public user tests were conducted for the purpose of this thesis. Their focus was to discover whether such system has an ability to motivate people to change their behavior and how emotionally engaging it

is. There is a detailed insight on the design of the nudges, the response towards using headphones as an interface and finally on interaction with Foursquare as another system.

1.2 Liminal Space as Urban Computing Paradigm

The main motivation force is the idea of space where technology becomes active and mediates transmission of meanings between different actants and the scales. It is the proposal of the design for the next era of urban computing[1] where technology has power and means to act. The term "liminal space" itself then points towards the re-organization of the known elements constituting urban experience. The aim of this concept is to provide an ideological and theoretical foundation to create a new types interactions, applications and devices, that will focus on local and global awareness and support various assemblages of entities and communities in the contexts of all scales: our homes, office buildings, neighborhoods, whole cities, countries or consequently even the whole planet and the biological habitat. This approach simply prefers interfaces that support engagement through monitoring, visualizing, reminding and persuading as the main functions of the new tools based on the data coming from the environment and applications working with large numbers of human and non-human users and their collectives (institutions, stakeholders, environment), coming from different scales connected through APIs.

The notion of liminal space is building on the shoulders of computing pioneers, such as Doug Engelbart (1968), who was a strong proponent of augmenting human intellect by computing technology. Engelbart saw this augmentation in terms of *partnership*, rather than just pure *use of* (technology). We can argue the interaction paradigm is somewhat rigid and

represents the modernistic hierarchy and emphasizes the notion of "user" as a measure of all things. This interaction paradigm, though, is not suitable for the interaction with public space. The cities of present are large organism-like structures that integrate great numbers of interacting actants. These complex configurations need a new approach, new paradigm that will enable circulation and translation of meanings between actants.

This thesis tries to present a concept of a urban computing design paradigm, so-called "liminal spaces". It is theoretically constructed around notion of different spaces or different scales. In liminal space, the focus is on the *connection* between them. Simply put, it proposes to focus on the interaction and exchange between the different scales[2]. The strategy to achieve this is to integrate companion and connected devices with situated technologies to re-focus from *interaction in space between humans* into much more exciting *interaction with space and its residents*.

Liminal space is a complex theoretical construct aimed at creating a framework for design and offers an interesting alternatives to present approaches. Mainly, it considers contemporary technology and its applications much more equal to humans than other approaches and it strives to symmetrize the relationships between the entities that create the city ecosystems. It sees the technology as more demanding, active *partner* in interactions of wide range of elements, both semiotic and material.

1.3 On Methodology - Integrating Theory and Practice

The structure of this dissertation is centered around three main areas: presenting the contemporary theoretical debate in relevant research areas,

propose the novel approach to designing urban computing applications and devices and finally, testing the approach on Navinko, an urban computing application for iOS that I co-created at Keio University, School of Media Design as a part of my doctoral research course.

The theoretical review two main streams of thought that it later synthesizes to construct the notion of "liminal space". The first stream is contemporary debate urban computing, a multidisciplinary field that brings together engineers, designers, artists and architects. The latter is philosophy and its application human-computer interaction, similarly open field that occupies itself with the debate about the way technology should be structured to meet the human needs (and desires).

After presenting the the theoretical arguments and building up up the theoretical framework, this dissertation proposes the concept of "liminal space" as a synthesis of Latour's Actor-network theory (Latour, 2005) and its notion of non-human agency with a contemporary theories of ubiquitous and urban computing, especially centered around work focusing on theoretical design approaches, such as Malcolm McCullough's presented in *Digital Ground* (McCullough, 2005). The conceptual chapter then moves on to debate on how to put the concept of "liminal spaces" to design practice by presenting the ANT concepts that serve as tools to develop the continuation or perhaps extension of McCullough's argument on design of ubiquitous computing applications. Where McCullough sees importance in firmly placing the design in the scales and types of places he discusses, I would like to propose go further with design that intentionally reaches out and connects these scales. To achieve this, the theoretical tools and recommendations are coupled with design thinking, a practical methodology that integrates the whole design process.

1.4 The Potential of Information Technologies to Solve Wicked Problems of Contemporary Cities

The contemporary cities are presented often as sets of what Conklin (2005) calls wicked problems, which we are entangled with as designers as Norman (2010) points out. Personal decisions of the inhabitants may have far reaching effects on thousands of others. One of such problems specific to Tokyo, for example, is a suicide in transportation system. Suicide, a tragic outcome of one's life, is a product of long lasting effects on a person, that may include workplace problems, family history, etc. It is a personal decision, that influences consequently lives of thousands of other commuters when it all ends with the act of jumping under the train. That triggers another set of events. The trains stop. It is often not only one line, but multiple lines in the station where they share tracks. Tens of thousands of people are trapped inside without the possibility to get out, often during peak hours when the trains are at the limits of their passenger capacity. The train conductor together with other staff face a tough job of removing the body of the deceased, people are late and they have to hurry. Suicide and its consequences present a wicked problem.

The wicked problems are often culture related and specific to each city - Tokyo has suicides, while Shanghai has a smog (Tao and Song, 2010), and Los Angeles with public transportation (Scott and Soja, 1998). They also differ on the scale and can range on the scale from the whole city to a particular neighborhood, a park or a city block. This consequently complicates the work of designers, increasing the needs for ethnography research and culture insight. And while the major rise of urban computing is still ahead of us. We can see the potential benefits that increased availability of information provides, yet we often cannot create a designed solution for

contemporary cities.

These efforts are still at the beginning, balancing between experimental artistic a locally very limited projects on one hand and very limited mobile applications that work with location context[3]. Most of these are not really creating anything new, only simplifying certain tasks. Our focus, as I argue, should be on discovering new possibilities for interactions with the space.

The question is what role can technology play in the development of cities over the course of next decades. Smartphones have become very personal and there is a whole movement of people who just cannot live without them. And it is not about not being able to call someone, but we rely on data and access to it anywhere. It is an outsourced, always connected part of our cognition. We are tapped in the information world of, constantly receiving and retrieving information that we need at that given point. Maps, location related data, train schedules, news, weather. Those are information that may have location context, but there is no real connection, or better said, exchange with the actual physical place.

We can start imagining the new application that would reverse order of Foursquare (and other apps) where user reflects the physical action in the space within technology. We are getting stimuli from the real space (moving around, interacting, commenting) and use technology to share, document, socialize. How can we reverse the order to use technology to act in the physical space based on stimuli. Create technology that will nurture interactions with the physical space to tackle problems using Actor-network theory, focusing on creating technologies that will emphasize the agency flows between the diverse actants in the city.

Chapter 2

Literature Review

Figure 2.1: A busy street near Shibuya crossing. A typical setting for Urban computing applications. Photo by author.

Urban computing has a difficult, yet beautiful position of working with people, technology and the city space. Places with high density of all these three elements, such as the busy street in Shibuya on figure 2.1 present great sites for design. There is glowing screens, there is people, smartphones, embedded QR codes on posters, shops offering discounts accessible through smartphones, digital content created and shared about locations, discussed in real time... The design for such environment draws upon multiple fields and disciplines. There is a need to understand both technology and its

design, as well as the city and theoretical approach towards urban space. This chapter maps the basic theoretical foundations and contemporary research effort in urban computing itself, understanding the city. Further on, it discusses social science theories and their application in computing to build support ground for introducing Actor-network theory and construct the notion of liminal space as an alternative vision of next urban computing paradigm.

2.1 A Brief Overview of Urban Computing

Urban computing is a design research field that is gaining increasing attention in the last decade. Urban computing explores information technologies deployed and used by public in urban areas. The popularity of urban computing comes in hand with the acknowledgment of the city and mobile as a new setting for post-desktop generation of computing revolution. Interaction with technology in public space of dense urban areas became an interest for many researchers, thinkers and designers. Ever since Mark Weisers time who popularized the prolific idea of information technologies freed from the office tables invading space and physical objects, scholars across many disciplines talk about the near future and the impact of ubiquitous computing. This is reflected by the number of generic introductory paragraphs perpetually repeating throughout journal papers with differing foci (Haeusler, 2009; Paulos, 2010) citing now almost legendary works of Weiser (1991a,b, 1993a,b) and others. Urban computing, in its broad sense, encompasses two distinct groups, one of companion technologies, represented by archetypal smartphones, and the second one, technologies situated in space that user can interact with.

Until the widespread of ubiquitous connectivity and smartphones, Varnelis (2008) says, urban computing was represented by avant-garde of artists

and researchers. The concept of "liminal space", presented in this thesis addresses urban computing as a design field. It proposes to join the companion technology, that is by now deeply rooted in our daily lives, with technologies situated or embedded in space. Such effort, as I argue, has a potential to start a paradigm shift in urban computing design.

The history of urban computing is goes back over two decades to the famous work of Mark Weiser (1991b) on ubiquitous computing, that sparked the interest in mass deployment of information technologies in physical space. Through the first decade of 21st century, city was acknowledged as a setting for the post-desktop computing by Mitchell (2004), Rheingold (2001) and others, who saw it as a logical extension of social media, liberated from homes and offices by the smartphones[4]. The second stream of urban computing strives to embed technology into the physical space and have it collect data about the usage of the space, environment, traffic, social activity in the city. Generally, these projects are not at the same level of market deployment as smartphones and there is little of the functioning ones.

2.2 Urban Computing: From History to Present and Beyond

"Urban computing as" a term is attributed to Eric Paulos in 2004 (2010), although as a theoretical concept it exists for over two decades. Urban computing quickly gathered interest from multiple fields that have their stakes in it. Urban computing is at the intersection of multiple fields. Design of technology for the urban space includes not only software and hardware design and related disciplines, but also reaches out to architecture, policy, culture and art. Each of these fields have their own theories, methods and

practices and the purpose of this review is to cultivate a space for the concept of "liminal space" as a new paradigm of urban computing.

2.2.1 Origins of Urban Computing

In academia, urban computing as a term was established in publications across a number of journals, such as Pervasive Computing journal. A large portion of urban computing debate became tied to the workshop "Digital Cities" held periodically in different venues. While the workshops under this name exists since 1999, the urban computing contributions are largely prevalent in the past few years. Selected workshop contributions were then worked into a collection Urban Informatics[5], at present one of the most influential publications (Foth, 2009).

A range of disciplines, such as design, design research, HCI, art, engineering, sociology and even psychology approach urban computing as a research field. There is a number of stakeholders with differing approaches: the "melting pots" are research labs often competing in innovation defining their own research fields stating their own approach differing from others, universities with interactive media programs or even companies doing design research with focus on deployment of innovative services or technologies, each of them striving to brand their research or contribution to it, or alternatively earn profits for its shareholders[6].

Some, like Haque (2008), are skeptical towards urban computing, comparing it to "rural electrification" or "horseless carriage", something that will very quickly outdate. To that we may object that archetypes in other design fields, such as "automobile design" remained the same for decades, yet the actual design processes completely changed [7]. It is a fact that in 1960s and 1970s, automobile was mechanical object, with few attached

electronic parts, while as in 2011, automobile is more a computer that has some attached mechanical parts that it controls. We may see similar direction in design buildings, or even other public spaces in the near future.

Similarly we could argue that "mobile phone" is not, in fact, a mobile phone anymore. Rather than that it is a computer that takes on a form and function roughly resembling Alexander Bells invention mostly only because of the interaction patterns of putting it up to our ear, something that is given by rather physiological nature of our body. Other than that, there is very little left from the original invention. We can thus argue that hopefully, as cities will become "computerized", urban computing will establish itself similarly as other research fields, rather than vanishing into the history, or being merged with architecture or some other design field. Or it will indeed vanish and urban computing as envisioned by todays researchers and technology enthusiasts will become a relic-vision similar to "cyberspace" and "virtual reality"[8] of the last decades of twentieth century.

We have to agree with Haque (2008), that the connection of terms related to city and information technologies itself is far from falling under the label emerging anymore, yet there are still ongoing discussions about definitions and scope of urban computing. Greenfield summarizes the term as implementation of mobile and pervasive computing applications in the public space. Adopting the perspective looking beyond the location and related data exchange around the location context over a mobile phone screens, a majority of research in urban computing is focused on the technological side and stretches the contemporary technologies further to innovate.

The technical innovation is, indeed, passing from the actual research to mass application, making the previous art - research - design clusters looking deprecated. The technological innovation, pushing further the limits of silicone and it use in chip design[9], can often be projected to the near

future[10]. One example is location awareness that first became a subject of design research and art endeavors (Varnelis, 2006) and then with the wide spread of accessibility of the GPS devices and city-wide internet connectivity it evolved into location services that fuel economy of many companies, such as Uber[11] and EggDrop[12].

At this point we can argue with Greenfield that actual locative media, as a research field or an innovative technology for artists to experiment with, did become deprecated. A number of applications for both Android and iOS, document this fact. The question thus remains whether urban computing remains just a process - something we could maybe call an "urban computerization", or whether it will establish itself as a viable design field, incorporating a body of design theory and methods in practice. I argue that it will become a specific design discipline differentiating itself as a specific field integrating interaction design, software and technology and urban design.
Once established as a design field, rather than just a research, urban computing needs to start attracting different disciplines. The position of urban computing in relation to disciplines is interestingly entangled. Looking at other highly highly developed design disciplines, such as car design, we can see that these call for collaboration of many different expertise - art, design, engineering. The role of interaction designers that approach urban computing as pioneers calls for combined knowledge of multiple disciplines. At this point it is clear, that we need multi-disciplinarity, that combines knowledge in multiple fields, or even trans-disciplinarity, that brings methods applied in one discipline into another.

The knowledge of computing, architecture and urban design, social sciences, namely philosophy and psychology combined all together presents a great challenge for orientation and learning. Rather than going back "to the roots", I chose some work to draw upon, especially with comput-

ing and psychology and philosophy. Urban computing stands at a similar point as field of Human Computer Interaction. HCI researchers look into psychology and philosophy and often borrow concepts, data, experiments to devise new types of interfaces, approaches and devices that are designed using these approaches.

Departure point for this thesis is bridging various applications of information technologies in public space. I argue that we can arrive to understanding the trends in the proximity future and that drives what needs to be involved in this body of work. Yet, we still have to acknowledge that "social, psychological, aesthetic, and functional factors all must play a role in the design" (McCullough, 2005).

2.2.2 Early Urban Computing Projects

The first collection of works in the field was the special issue of Computer journal (Shklovski and Chang, 2006) named *Urban Computing: Navigating Space and Context*. In 2007, three other collections were published, only three years later after the actual coining of the term. One was a featured "work in progress" theme of Pervasive Computing journal. At that point, it was acknowledged that urban computing indeed has a very large focus and is not established as a research field or interest, the editor of Pervasive Computing Journal briefly sums up the situation: "we have 12 urban computing and mobile device entries that span a wide range of computing and social areas" (Joseph, 2007). This edition of the journal features now seminal projects that defined the beginnings of research effort in information technology applications aiming at public space.

As examples we can take MIT Media Labs Wikicity: Real-Time Urban Environments (Ratti et al., 2007) and their visualizations (see figure 2.2)

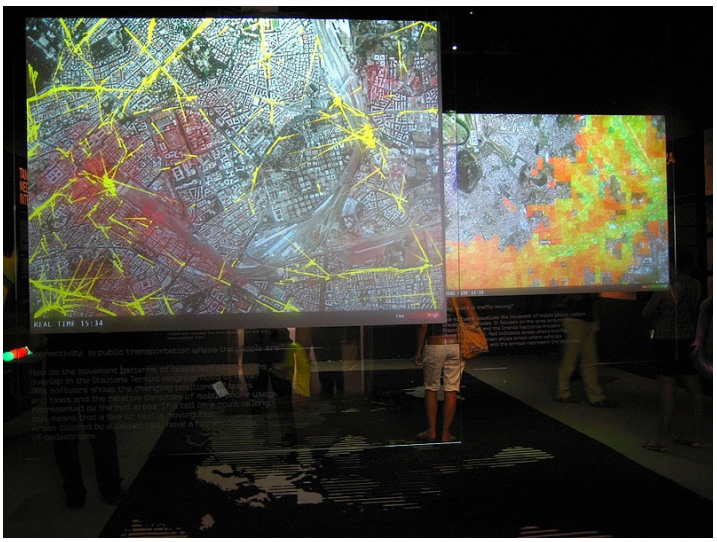

Figure 2.2: Sketch from WikiCity subproject Real Time Rome. Source: Real Time Rome website.

or Mobile Location Bookmarking (Bilandzic and Foth, 2008). The other projects featured include: Social Patchwork: Urban History Lines (Foth and Klaebe, 2008) that overlays new maps with historical ones. Tracing the Visitors Eye (Blat and Nova, 2007) analyzes spatiotemporal data (long., lat., and timestamp) to discover "high-level human behavior such as mobility mode". The second was *Space, Sociality, and Pervasive Computing special issue of Environment and Planning B* (Dave, 2007), while the third was *Urban Informatics: Software, Cities and the New Cartographies of Knowing Capitalism special issue of Information, Communication and Society* (Ellison et al., 2007).

The prevalent theme of an early urban computing research is, as we can see from the titles of the journals special issues and the actual titles of papers, location technologies and location context and mapping. Experimenting with location was prior to that domain of new media artists, before it became focus of design research. At that point, market-deployed location services (not installation or prototypes), were scarce and prevalent applications deployed were GPS navigation tools with large map installations.

Figure 2.3: Handheld GPS receiver from 1990s. Archive of author.

Prior to that, so called locative media (Varnelis, 2006) experimented with GPS technology and physical space in artistic forms, such as .walk ("dot-walk") presented at the 2004 Transmediale festival in Berlin. These novel approaches to cartography and the specifics of GPS technology itself contributed strongly to the conception of urban computing research field itself.

While the new media art certainly contributed to the development of these services, thea biggest motivator probably is the actual price drop / miniaturization of the technology itself that made it to find its way into the majority of smartphones. The fact that such technology is now accessible to such a large market certainly influenced entrepreneurs to invest and produce services focused around the location sensing. As of January 2012, the "next big thing" is supposed to be so called Near Field Communication, NFC, that is supposed to be implemented into several smartphones scheduled for release this year. The NFC, effectively an extension of RFID technology, allows to blossom services, such as micro payments, replacing all sorts of customer reward programs that filled our wallet with customer cards, allowing our identities to be linked with "touching" a physical point in space equipped by a reader, that can be linked to Facebook, Twitter or other social media for automatic content production - liking, tweeting "plusoneing" and others.

While location is no longer the general focus for mainstream services casted into our mobile phones, sensing positions of other elements, rather than only people, still continues. For one example, we can take "Trash tags" developed in MIT that track garbage and researchers use them to observe disposal patterns within neighborhoods (Boustani et al., 2011).

The integration of mobile technologies and various types of sensors seems to be driving innovation successfully. Accelerometers and gyros that interpret our activities, sometimes the internal ones, sometimes in the form of

accessories, like Nike Running, or Jawbone UP[13]. Similarly, we can expect other sensors to follow the GPSes, accelerometers and gyros, offering finer and finer grain data about the ways our bodies interact with space and objects that surround us.

2.2.3 Contemporary Urban Computing Efforts

The important difference, that leads to the concept of liminal space is the different approach to scales of these technologies and applications, not being primarily focused on the portable devices, rather than that, as Kuniavsky (2010) notes using them as handles for services. Going further, these devices will also become handles to physical space, physical infrastructure of the cities. The research themes and efforts going beyond location itself, emphasizing multi-modality and bridging different types of technologies generally start to emerge in approximately the last two years.

We can observe this shift both in the Situated Technologies pamphlets and urban informatics research field. The position data itself connected to providing contextual information placed in physical space relevant to the place where user is becoming research focus of digital signage. This shift, however, now needs more than independent researchers and designers with access to technology that is portable and can be easily deployed. There is often a need for complex collaboration between with different stakeholders, especially because often the owners, laws and rules governing the parts of these systems (private handles, semi-private business oriented mobile networks, private or municipal public screens) differ so greatly. One such example is urban media testbed built in Oulu, Finland (Ojala, 2010). Oulu testbed is built of "three types of wireless networks ... large public displays and various server machines connected via aerially large layer 2 network" (Ojala, 2010). These testbeds and frameworks allow designers to use various combinations of resources that allow for creation of various different

applications.

While there is not a chance to construct an extensive system integrating multiple technologies, we can find some examples that accomplish similar goals with different types of resources, integrating existing infrastructures everyone has an access to, such as social media and mobile connectivity, with some specialized part, such as public screens. One such example is project carried out in Sapporo that stimulates citizens to share their content on the displays situated in public places where people often gather (Seeburger and Choi, 2011).

Testbeds and framework multiply possibilities for design. They allow for new combinations of data and interactions in the public space, arguably far more that locative technologies themselves. We have to keep in mind, that locative technologies though often become a part of these testbeds. I will discuss the importance of city-wide frameworks that can be constructed with a bottom-up approach of open systems that can join a larger network formed through open joints, represented by various APIs.

These projects propose to give users the possibility to create and share content, while displaying it in public space. The displays are physically public, but I argue that these are very similar to traditional social media, where the interaction scheme is similar. Embedding content in the environment, providing it with context, is traditional approach, that, I argue, is not powerful enough to disrupt the situation around current urban computing paradigm, unlike multi-modal and situated technologies.

2.2.4 A Different Take: Situated Interactions with Situated Technologies

While the above mentioned research centers around technology, information systems and their design, there are also slightly different approaches. One of them I chose for this review is Situated Technologies research group. A joint project of Omar Khan, Mark Shepard and Trebor Scholz from University at Buffalo, School of Architecture and Planning and Institute for Distributed Creativity. The main outlet for the discussion within architectural field with overlap to other fields is the Situated Technologies Pamphlets (Haque, 2008). Published roughly twice a year from 2007 each pamphlet is focused on different phenomena or part of discussion.

The Situated Technologies series provides great introduction into the field and often provide intriguing ad-hoc constructed theoretical backgrounds. The use of technology within their line of thought is often rather art-oriented without necessary involvement of technologies previously associated with urban computing. For that reason, I chose two projects presented within the Situated Technologies pamphlets as case studies for this literature review and they are explored in-depth further in this chapter. The bottom line of the discussion in Situated Technologies is, as the name suggests, how can we enhance either a place or a space so that the technology becomes part of it, rather than give user a tool-mobile device to interact with it.

This approach favors a tight coupling of technology tailored for the specific place as well as specific interactions. Such projects often construct innovative interfaces to draw attention to various types of data, such as in case of Amphibious Architecture by Jeremijenko (2009). The narrative, transformed into recently published Sentient City book (Shepard, 2011) discusses other applications, that bring into interaction other entities, such

as Usman Haque's Natural Fuse (Shepard, 2011, chap. 3).

2.2.5 Beyond Screen-Based Interactions for Physical World

As we can see, the screen, once a paramount of the human-computer interaction as the main visual output, is being joined by other modes of "communicating" with a computer system. One of the most compelling of this refusals of current computing paradigms was coined by Bret Victor, who summed the obsession with embedding displays in to car windows and other surfaces as a "vision, from an interaction perspective, not visionary. It's a timid increment from the status quo, and the status quo, from an interaction perspective, is actually rather terrible" (Victor, 2011). Tracing the roots of screen-based devices back to 1960s Victor points out to the work of Alan Kay, who in 1968 - three years before the invention of the microprocessor - stumbled across Don Bitzer's early flat-panel display. Its resolution was 16 pixels by 16 pixels - an impressive improvement over their earlier 4 pixel by 4 pixel display. Kay saw those 256 glowing orange squares, and he picked up a pen and drew a picture of an iPad.

Victor calls the touch-based interface "picture behind the glass", which is a beautiful metaphor describing our every day experience with these devices. We basically touch glass and manipulate the image behind it. Victor points out the need change this "picture-behind-the-glass" paradigm by designing different interfaces and tools that will address our real world problems. In other words, he calls to to designing different types of interfaces, ones that transcend the paradigm of the screen. What Victor intends to point out, but not directly saying it, is the fact that we need to design interfaces that will take greater advantage of our bodies and senses. There are multiple ways of addressing such design, I decided to focus mostly on the augmentation and an effort to avoid simple screen interface.

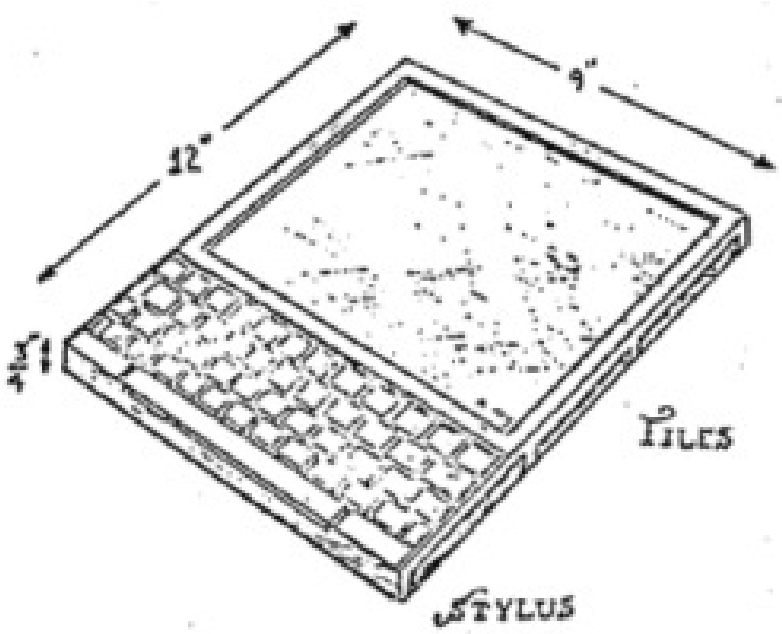

Figure 2.4: Alan Kay's concept touch-based device from 1968. Source: Wikipedia.

It is sometimes impossible to remove the screen user interface completely, but it may be possible to demote the screen to some sort of support interface, that will be used to display information and control, but the main part of interaction would lie in different realm. Another reason and important point is that from the technological point of view it is rather difficult to augment vision and design interface that would allow interaction in public space and would be seamlessly integrated with the user herself. It is thus much easier to design conceptually for different sensual inputs then visual (touch, hearing, etc.). Navinko demonstrates this potential of other types of interfaces with sound, where the smartphones server for computing and communicating. The screen is secondary and is used only for necessary setup.

Looking into the near future of urban computing will look somewhat similar. While we look at the present situation in urban computing, we have

to acknowledge multiple streams of research and deployment of these technologies. The liminal space approach that I propose is focusing on activity and behavior of the people in urban space and presents an alternative, that both takes an advantage of current habits of users and high market tide of smartphones, as well as the potential of technologies embedded and situated in the space.

2.3 City, Technology and People - The Influence of Urban Design

For centuries, the urban design and innovation in cities was in hand of architects, urban planners and regulatory public institutions. They were those who occupied themselves with crucial questions such as "How can we design the real innovative city?" Cities have not changed for ages. Science fictions depictions of the cities in the future focus on physical design, very little talk on the actual interaction. I already mentioned Minority Report where target advertising based on retina scanners presents an approximation of technological advances projected for next number of years. That is not any paradigm change. In present, the worlds megacities have so many problems influencing their livability - ranging from social to constructional. While technology usually serves very well to those like improving the city throughput for vehicles (see Tokyo highways below), we can argue that it is failing to be put to a good use in a subtler, softer social issues.

The task here is to weave information technology that will stimulate our behavior into the fabric of our cities. Now these systems exist on top, or maybe next to other city infrastructure, but are not part of it and by far do not play role that be suitable for their potential.

Urban design practice and theory had always seen itself as having a monopoly in the way our cities are built. This is changing and subtle infrastructure of information technologies enables all sorts of others to engage with and influence the way our cities will look like and the ways we will be able to interact with them and each other too. Collecting badges in Foursquare is beginning, the real question is though how can we use these technologies to stimulate action in real, physical world. Looking at the urban design history is very inspirational - urban designers look to it to understand the users of the city to create better designs, interaction designers who aim at the public places should look at it in a similar way a benefit from the accumulated knowledge from other fields. The shift from understanding city as pile of stuff through background environment place of activities towards an interface that mediates sums up the debates reviewed in this chapter.

The reason to do this is because we need a method to design active places that will stimulate and engage users. We need places that will have personalities. We need places where our anthropomorphic understanding of our surroundings will be stimulated by human-like technology that will remove the absolute control from our hands and rather than that lead us, educate, entertain or whatever else.

2.3.1 City as a Pile of Stuff

Kevin Lynchs book Image of the City (Lynch, 1992) attracted a lot of attention of contemporary practitioners in fields related to urban computing was also very influential in 1960s when it provided a coherent taxonomy for mapping and description of urban space. The general concept of this work is a city seen a a collection of artifacts, physical space arranged in some manner. Lynchs distinction of paths, any corridor that allows movement, edges that divide them, districts - the parts of the city with distinct char-

acter, nodes, also called cores, high density places and finally landmarks as external points of reference shows his view as strictly empirical. This basic and among urban computing researchers often cited works gives us overview of city structure and furthermore provides material to work with: lets take for example paths and edges that, together with landmarks, constitute guides for navigations in our city. While it may change the way we interact with space - as we can already observe with appearance of mobile navigation devices first and massive penetration of GPS-enabled mobile phones in last few years.

Figure 2.5: A view on highly urbanized part of Tokyo. Photo by author.

While Lynch identified these five elements as the best way to characterize the city, yet he is not describing or acknowledging the way people map the city together and give the systematic mapping of cities in an in-depth analysis and theoretical update, Dalton and Bafna analyze Lynchs thinking further (Bafna, 2003; Barkowsky et al., 2007). They identify his empiricism

as a possible point for a critical reinterpretation from a point of view of syntactic spatial research. Their argument brings in the social dimension, yet the main focus is still the material characteristics of space.

2.3.2 City as a Stage for Activities

Later approach that became a center of focus from early 1970s shifted its focus from pure organization of matter towards more subtle distinction of various social elements. Activities in public space. According to Jan Gehl's classical book recently reprinted (Gehl, 2011), the activities within the public space are of three types. Those (i) necessary ones that we do because we have no choice, (ii) optional ones that we may or may not do based on various conditions, but mainly our own wish and lastly (iii) social ones that depend on presence and interaction with others.

The necessary activities are those such as walking to work or waiting for a train. Commuting, shopping, errands - all of these somehow require us to participate, which means that we cannot easily opt-out from them as they are conditional for carrying out our lives. They can also be specifically related to our jobs - such as Gehls example of mail delivery, but we may think of many others. Handing out flyers trying to bring attention to a new store opening or distributing promotion coupons for nearby izakaya also fall into this category. Gehl notes that most of these activities are related to walking, or maybe in a broader terms and larger scale extend to public transport as well. The optional activities are those that we do to enjoy our time while being outside. Sitting in the park eating lunch and reading book. Enjoying view from an elevated place in the city or going for a walk to take a breath of fresh air.

Similarly, going alone for a stroll during the weekend would fall into this

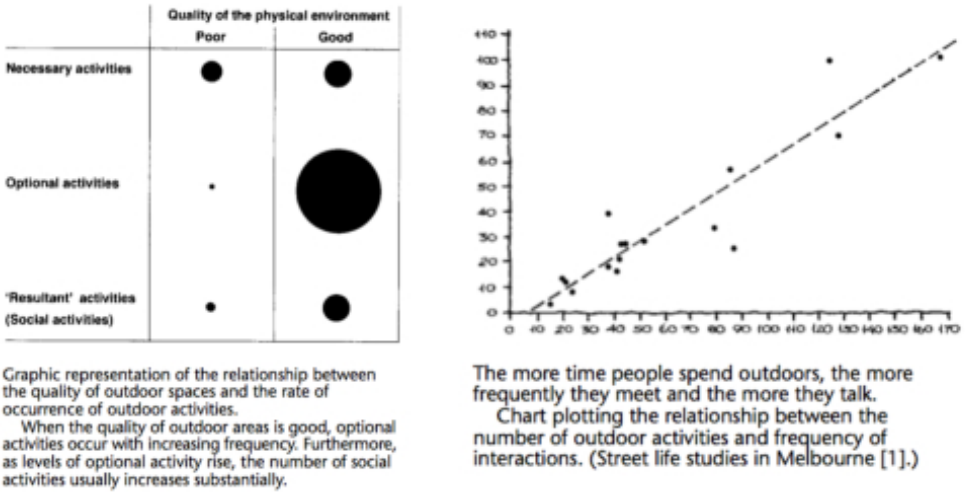

Figure 2.6: Gehl's interpretation of types of city activities. Source: (Gehl, 2011).

category too. Gehl points out that these activities, as they aim at bringing enjoyment to the one who performs them, are taking place only when the conditions (i.e. the quality of urban space) is optimal, "when weather and place invite [people]" (Gehl, 2011). Thus, when the public space of the city is not a good quality one, people will refrain from performing these optional activities and will most likely spend more time in their homes. Good urban design invites people to engage with these activities to stop around and enjoy their time eating, drinking coffee or reading outside. The importance of the affordance of public space, to put it in design terms, lies at heart in the social transformation that gave rise to public sphere and civil society of 20th century (Habermas, 1989).

Social activity is the last category, that even Gehl notices as the most important as well as the one that is most demanding on quality and design of urban space. Interestingly, he notices just a passive engagement of hearing others conversation as a social activity, rather than including just the active part of social engagement. From this broader point of view, social activity happens everywhere in the public space where two people meet and

share the same space. This can be dwellings, benches in the square, public buildings or parks, taking into account only those places that are publicly accessible. As such, these activities are resultant of the two previous ones. Gehl notes an importance of physical design for that, saying that designers and planners directly influence and can induce the social activities by design:

"Although the physical framework does not have a direct influence on the quality, content, and intensity of social contacts, architects and planners can affect the possibilities for meeting, seeing, and hearing people possibilities that both take on a quality of their own and become important as background and starting point for other forms of contact." (Gehl, 2011, p. 144).
Gehl also later argues for the importance of soft edges, distinctions between building and public spaces (Gehl, 2011, p. 170) that offer some engagement and welcome the optional or social activities, "easy access in and out, good staying areas ... something to do ... directly in front of houses".

While Gehl creates a taxonomy that he uses for city analysis based on affordances for social activities, William H. Whyte researched even subtler phenomena that influence peoples interactions in and with space (Whyte, 1980). Before having effective computational tools, Whyte have used observations, ethnographic research and even unconventional tools, such as time lapse photography to analyze, for example, the importance of amounts of sitting places, sitting heights, the amount of sunlight. Both Whyte and Gehl both look for methods how to make urban space more enjoyable. They tried to find out and then present through narratives ways how to raise social engagement in public space.

2.3.3 City as a Digital Playground

Thinking within the overlap of the three mentioned concepts in previous paragraph, it is useful to mention the notion of a Hertzian space as an overlaying cloud of electromagnetic waves that was spread out over the cities we live in and that it is getting thicker and denser with every day. The proliferation of smart phones brings near-future research projects from few years ago transformed into services for the masses - location based application that we can see emerging especially during last two years (2010 - 2011) might seem to a researchers from 2005 like a dream. Location based community shopping - Zaarly or Eggdrop that allow users to search their vicinity for shopping opportunities promise to redefine terms as garage sales by connecting people who think they need to buy something with those who have anything to sell.

The rise of connectivity and emerging possibilities that promised mobile technology to be used everywhere. The general idea that we will soon be able enjoy all the features of public and social life from our homes was largely prevailing. In the contemporary literature, we can thus read that proximity matters no more and that communication technologies are working in favor of city decentralization in the same way as automobile did few decades earlier (Gordon and Richardson, 1986). With a decade and more of a distance, we read that in the post-information age there will be no geographical limits (Negroponte, 1975) and that cities will fall into never-ending suburban group of homes eliminating any need for city centers as hub for interactions. The situation starts to change with the technologies becoming more and more mobile promising further future developments. Sometimes around the beginning of new millennium we can read first acknowledgment and observations of the technologies populating the public space. In a paper called How Telecommunications Systems are Transforming Urban Spaces (Moss, 2000) we can read about internet soon invigorating

public spaces such as airports where people will be able to interact and do business.

It is before locative media when people realized that location context, the first situational information that changed the way we think about technology in the city was possible only thanks to GPS, a network that provided location information anywhere and coupled with internet access, first over WiFi and later through GSM and other mobile infrastructure. Adding information and communication to physical objects then became a holy grail of many researchers. William Mitchell explored the consequences of wired and wireless networks in Me++ (Mitchell, 2004), yet did not fully grasp the social potential for shared interactions. Rheingold saw the embedded technologies as a remedy towards a physical realm where people physically reside while being focused on virtual experience (Rheingold, 2001). The shared presumption was that the information society will somewhat replace the industrial one, yet it basically coupled with it (Thackara, 2005), creating a dangerous mix where technology proliferates and often creates situations in public space that are undesirable and culturally specific - such as talking on the phone in train in Japan (Ito, 2004, 2005a,b).

The key point in this debate Mitchell, though, clearly identifies the vision that we have to find a way how to design flexible, diverse and humane habitats through abandoning architecture of stable routines and spatial patterns and embracing "continually reconfiguring clusters of spatial events characterized by their duration, intensity, volatility and location" (Dugopolski, 2009, p. 163). Dugopolski, quoting Thackara, states that "wireless access to the internet increasingly renders the whole city, not just its buildings, equipment and furniture - an interface" (Dugopolski, 2009; Thackara, 2005). In other words, technology should really help us to devise new ways of using space, creating and abandoning places that will have social functions using technology not to transcend into virtual de-placed world, but

Figure 2.7: Two views on Shibuya crossing. Top, 1991, before digital signage. Bottom, 2011, public screen saturation. Source: top - Wikipedia, bottom photo by author.

rather to interact and act within the real one. This focus on activity as an outcome of reconfiguration of public space is the important one. The activities can range from playful ones - an example of city park on a Sunday afternoon that is brought up so often is a good one - to the most serious ones where community engagement and emotional engagement tries to take on some of the most complicated phenomena such as suicides in the citys public transportation systems - a paper that I have written and presented at Communities and Technologies conference (Rod et al., 2011).

Constructing the urban space should then involve not only urban planers, architects, engineers, but also interaction designers who will be able to bring in insights into how to create these functional public spaces that combine spatial design with activities that can be performed in the space and that result into some sort of social change and improvement. The question of the city as an interface goes further beyond urban design and architecture and engineering and should, according to McCulloughs statement, render the interaction designer profession as one the most important ones, as they are a profession that can work through different scales and bring so much needed insights into what applications of ubiquitous computing should work and which should not.

Cities that should work as an interfaces become ever more complex with the information technologies embedded in them. A great part of the research that I have mentioned previously preoccupies itself with a city as a whole, urban space, cityscape, not providing enough fine detail on applications, types of interaction and other various factors. This will result, according to McCullough, to architectural failures. These failures are to be caused by the infinite combinatorial possibilities that the technology provides, while combined and coupled with technology. How do we then tame this danger that comes from infinite possibilities that are opening ahead of us?

McCullough suggests we go back to typology. While not explicitly mentioning Gehl that I used as an example of early taxonomical understanding of a city through activity, he offers us similar and fairly more structured typology as a departure point for design of technologies for public space. One of the reasons is that creativity arguably performs better while bound within certain theme and forced to think of variations rather than just with arbitrary innovation. As a tool and an examples McCullough lists thirty situations, proposing the categorization based on the type of place - workplace, dwelling place, third place (public, "in the town") and also mentioning "fourth place" as place of commuting and travel (Gehl, 2011, p. 119). The typology and description of each of the 30 types goes into great detail of activity. While these activities are distinctive, it is questionable whether they need a reconfiguration of the space as such, rather than just reconfiguration of tools within the space.

McCulloughs typology presented through sets of short descriptions should serve to protect designers from "arbitrary freedoms [that] often yielded dysfunctional spaces [and similarly] type defying, free form configurations will mostly not work in digital environmental technologies" (Gehl, 2011, p. 119). The speculative and somewhat ethnographical approach towards description of each place necessarily makes us think whether the typology cannot be created ad-hoc for each project that designers encounter. The specifics of McCulloughs place descriptions, such as "places for recharging" at home where one maintains her body, or places for "cruising" annotated as "places for seeing and being seen" (Gehl, 2011, p. 134) is focused at the activity that individuals perform and the analysis of the activity then potentially yield some space for design intervention.

McCulloughs distinction of four places, which extends the original Oldenburgs classification of three (Oldenburg, 1989), is projected into basic categorization of the examples. Emphasizing embedding and local con-

text McCullough criticizes the original ubiquitous computing that "mostly been a matter of pure mobility, with a little regard for locally embedded systems"(Oldenburg, 1989, p. 142) that would provide contextually relevant information either to a place or to an activity performed within the city. To work out the connection and exchange between local embedded systems and portable devices is, according to him, vital to devise better "...patterns, protocols [and] ownerships...". This understanding is almost in direct opposition to what Mitchell was thinking only few years before McCullough.

The key feature of situated technologies, thus, should be working through the scales of place integrating technology on the levels of (or in) our bodies, at hand, in the room or within a neighborhood. This goes against the idea to the totality of information sphere where all information is available to all people at all places at all times. Such idea, prevalent in until recently, is what McCullough names as danger for ubiquitous computing applications. The information overload, inability of such systems to deliver relevant information at relevant time readily enough are the main concerns that McCullough cites (McCullough, 2005, p. 213). Greenfield also notes that "a sensitively designed everyware will take careful note of the qualities our experiences derive from being situated in real space and time" (Haque, 2008, p. 74). However, while he mentions the transformation of public space, he talks almost solely about way-finding. Using Lynchs theoretical approach to legibility of the city that I sketched out earlier in this text, Greenfield puts emphasis on speculative and prototypical navigational systems. The persisting discourse of locative media and strong focus on location context at that time is clearly visible.

As we can see, the shift towards contemporary thinking of the city and public space as an opportunity for discovering new possibilities for social interactions that go beyond extending and perfecting existing activities is a

fairly difficult one. And it is especially difficult on the level of public space, which is, similarly to urbanism involved with the widest and most complex concepts. On the level of body, room, or a building, it is possible to design technologies quite straightforwardly, while the designing (for) public space is much more difficult - be it traditional urbanism or some urban computing application. The public space and its design is extensively researched area with many guidelines and observations, that range from the very complex ones to fairly simple and straightforward ones. The latter example might be an example of four elements needed for successful public space design: accessibility, comfort, people engaged in activities and sociability (Nasar, 1992; Sancar, 1994). While each specific project might need tighter and more specific design guidelines while another not, based on the focus and goal, urban design theory has a lot to offer to designer of technology and services and interactive systems.

Looking at McCulloughs diagram of different scales, each scale presents a possibility of design intervention. Some design can even traverse the boundaries between them and span across the level of building and public space, such as a street screen. There is obviously a lot of interaction and information exchange, data flow between the levels - from people to environment and from environment to people for example. Designing for the edges can yield some interesting results - such as interactive architecture, that focuses on how individuals can interact with physical matter or some sort of display or other actuated surfaces or objects.

McCulloughs diagram - focus on organization - scale and organization. But important are the edges. While we look at McCulloughs diagram, we get the false image that the edges between scales are hierarchical, but they are not, as we can see on . While I move in the public space, the highest level, my portable and wearable sphere edges with the neighborhood (public space) one. The edges also rapidly change. When I leave the building

and get on the bus, there three different edge configurations that can happen and disappear during seconds, just during the time that I leave the building, cross the street and get on the bus. There can be even more if I decide to take a subway and I need to go to the station. And each of these edge configuration is a design opportunity of sorts. While we could probably describe this as some sort of context, I argue that the concept of an edge is better as it stimulates thinking and somewhat bring attention towards the actual exchange and flow that is happening in between.

While we look away from the environmental issues, advances for architecture are most is most important development in material technologies - steel glass and various types of concrete (Haeusler, 2009) In recent years, the information technologies started making their way into architecture, changing the traditional approach to materials and redefining the way architects as well as other think about facades, for example. Seeing the opportunities for enhancing the buildings and its facade or the whole urban space with technology to appeal on those who walk by in the urban space brought what is today called interactive architecture.

While the overlap between digital signage, public TV screens and interactive architecture that is still struggling to find effective ways to actuate the physical space, is obvious, on the larger scale of urban design and urban planning the time has yet to come. It is a consensus that information infrastructure of the city is gaining similar importance as has the traditional infrastructure of water, electricity and roads, yet in terms of wide adoption of policies that would adoption of policies that would lead to its adoption we can still see a struggle.

The final argument here should be that there is a need for synthesis - Haques UVS etc. - We need to find a way how to use and make advantage of the technologies to tackle wicked problems and issues that we have with

the cities. That is not only talking about the environmental issues, but also about social issues. And finding balance. While we tackle social community issues with large screens, there is a serious doubt about the ecological effectiveness. And maybe the doubt is justifiable - why not looking at the shortage of resources here in Tokyo right now. That is a unique disastrous model for other cities.

Contemporary debate on the development of cities usually focuses greatly on environmental issues (Newman and Jennings, 2008; Zalasiewicz* et al., 2010), that are translated into architecture and urban design on multiple levels from building low energy demanding housing, districts or stimulating infrastructural changes for creating desirable environments, where people can enjoy cycling, have access to public greenery or use public transport that is accessible and clean (both in terms of energy consumption as well as the actual interior environment). While it is often a cultural issue (whether there is a strong culture of public transport or bicycle use), it is often hard to change the paradigmatic thinking about these everyday, yet deeply rooted issues that often relate to complex combination of issues such as climate, terrain, historical development and background, urban planning, culture, contemporary policy issues et cetera.

2.4 Social Science Theories in Computing Design

This thesis proposes adopting a different approach to design of technologies for urban space founded in philosophical and sociological approach to agency based on Actor-network theory. To understand how theories enter computing, I am reviewing two other examples of theories coming from social sciences, phenomenology and activity theory, that have been intro-

duced into design of information technologies as well as reviewing how they contribute to design of information systems or HCI.

Theories of social sciences have had continuous influences on various design fields - traditionally in industrial design and architecture (Yaneva, 2009a,b, 2010; **?**). While the utility of various theory-based approaches is known, it is no surprise that computing and HCI embraced them relatively early. The first comes from adopting phenomenology by Terry Winograd and Fernando Florres (Winograd, 1997; Winograd et al., 1996; Winograd and Flores, 1986) who attempted to implement it and demonstrate its usefulness almost twenty years ago. The second approach, far younger one, is Activity theory, popularized by Kaptelinin and Nardi (2006). I chose these two as they present very coherent and structured description of theory (and its development) and consequent case studies, while the theoretical approach lies at heart of the design process of the actual information system. This review will sketch out the basics of these two theories and very briefly show how their authors approached the design from within these theories. It is also useful, as I argue, to look at why these theories became influential in HCI.

2.4.1 Phenomenology in HCI

Before phenomenology the world was a dichotomized one: Cartesian mind-body dualism held sway and no thought was allowed to leave the mind and translate into physical world. Interestingly enough, the phenomenology taught us the concept of embodiment, or acting through the the whole line drawn between various concepts of human being and world that being navigates. Not from the very start though: Husserl, even though he was effectively founder of methodology, was perfecting Cartesian paradigm of mind-body dichotomy by emphasizing that true knowledge lies exclusively

outside the realm of physical world and cognition as such must then live in the realm of pure thought. Very much like early approach towards designing computers as human programmed information processing machines.

This approach towards computing lies at the beginnings of main cognitivist period of thinking about information systems that is represented by early computing pioneers such as Minsky or Chomsky in 1950s and continues to be very influential as one of the prevalent paradigms in design of artificial intelligence systems that focus on producing rationalistic algorithms to perform so-called intelligent actions. There are four basic principles of this approach: separation of mind and body, thinking is in fact manipulation of abstract representations, that can be expressed in formal language, deterministic enough to be coded into the machine.

According to Mingers (Mingers, 2001) this approach to artificial intelligence is very successful in certain limited tasks. He gives one that is very prolific and well know - chess. Chess relies on two basic mechanisms of forms of representation and methods of search. The situations to be intelligently solved can be represented in some computable way and then the system can search for most suitable solution. While this certainly works at chess game, Mingers (Mingers, 2001, p. 107) gives a blatant example of, rather than demanding computer to play chess, see whether it can place physical pieces on the chess board taking them from the box. This simply implies, that the tasks that we often see as the simplest ones (setting up the board) can be absolutely unapproachable from within paradigm of AI. However, the critique of cognitive approach to artificial intelligence systems has also started long time ago with (Dreyfus, 1992) and continued until 1990s (Okrent and Smith, 1996; Searle, 1990). Artificial intelligence, however, definitely finds its specific domains where such approach proves to be sufficient and where interaction with physical world and context are not necessarily important at all.

This approach changed with Heidegger, who he recognized how context-bound and situated our human activities are. Heideggers Dasein is surrounded with objects that we interact with, other selves and then ultimately the Dasein itself. These objects, while being used by Dasein, then disappear from the consciousness that focuses on the given task, until the Dasein experiences breakdown. This is the famous distinction of ready-to-hand and present-at-hand that lies in the center of the approach computing coined Winograd and Flores (Winograd and Flores, 1986). The fact that our general prevalent mode of interaction is in the mode ready-to-hand, we do not think about the function, composition and construction of objects we interact with in the everyday lives - we tend to navigate the space while looking at objects in the mode of use rather than the mode of analytic or descriptive thinking. That is why we tend to describe things relatively, often in our natural language in the way they are structured in space relatively towards each other rather than in the analytical way of some sort of absolute positioning.

This is characteristic for the understanding of Dasein as being concerned about objects, which is its general approach to the world. Similarly, concern is important in Heideggers understanding of way we interact with other people. In a public space, where Daisen is surrounded by other and does not interact with them. In this mode, they are just present-at-hand as we approach them from our solicitude. On the other hand while we do interact with them, we often tend to approach them through the sort of activity we engage with them - bank clerk, train station employee, officer. Finally, concerning ones self, that is consciousness of ones self, there is a central concept of thrownness that we always find ourselves in. Our states of mind are prior to consciousness, which is at the core of Being-in-the-World.

Synthetising Heideggers phenomenology with some other contemporary

theories of Gadamers hermeneutics (Gadamer, 1975), Searle theory of speech acts (1969), Austins linguistic theories (Searle, 1969) and Maturana and Varelas theories of autopoietic systems (Maturana, 1980) Winograd and Flores used it as a core of their approach to computing that is organized around the critique of traditionalist cognitivist approach to computing giving rise to a new one, that focuses on acting through language - so-called laguage / action approach. Mingers summarizes it "that cognition and thought is not an isolated, separate mental function but normal everyday activity ... It is embodied in the patterns of behavior which are triggered by our interactions and which have developed through our structural coupling" (Mingers, 2001, p. 110). Approaching problems and problem-solving in computing as conversations, Winograd and Flores developed a software called Co-ordinator that was based around speech acts, but was later criticized for rigidity esp. by (Suchman, 1994) and Winograd himself (Winograd et al., 1996).

The last, probably most elaborate approach towards cognition as essentially embodied activity was conceptualized by Merleau-Ponty (1962, 1969) and is called embodied cognition. Merleau-Ponty takes what might have seen a rather radical step: our consciousness and body are indeed inseparable and form one subject (1962, 408). This leads Merleau-Ponty to formulation of famous structuralist argument that our behavior cannot be explained nor in a behaviorist way as a sum of external causes, nor purely internally as coming exclusively from intentionality. Rather, he emphasizes the structure of cognition-body-world where the physical structure of sensation and perception develops circular interplay with the world. Or with Merleau-Pontys words - "The body is our general medium for having a world... Sometimes, ... the meaning aimed at cannot be achieved by the bodys natural means; it must then then build itself an instrument ad it projects thereby around itself a cultural world." (Merleau-Ponty, 1962, 146). The last question that is not addressed then is how the purely abstract con-

cepts exist, such as triangle in mathematics. To that, Merlau-Ponty states that they can be thought of as purely abstract, but they can be experienced only in the physical world. Similarly few decades later, Lakoff and Johnson base their theory of language around the structure of embodied metaphors. Accepting this approach that majority human cognition is indeed embodied, "then majority of information systems working with pure thought is actually working against rather than with natural human abilities"(Mingers, 2001, p. 121). What Mingers suggest is to design systems that are respectful towards embodied nature of human cognition and focus more on interactive level and decision making level. Subsequently he suggests to look at how the disembodied approach affected individuals and society.

The three phenomenological approaches centered around cognition and the development of its understanding can be easily interpreted and seen as the core of human-centered approach to HCI and design of information systems. Phenomenology in its three incarnations as described above it helped designers to understands better the relations between people and objects and how they are, function, in the real world. The trajectory that phenomenology sketched out still continues. Contemporary theorists and thinkers indeed still look into phenomenology as its theoretical resources still seem to not be depleted.

2.4.2 Activity Theory

The second example I am going to address in the literature review is aforementioned Activity Theory and its implementation into computing by Bonnie Nardi and Viktor Kaptelinin cite. Activity Theory is somewhat competitive to Acton-network theory and indeed both of the authors take a great time to explain the post-cognitivist paradigms and approaches to in-

teractions design.

Activity theory, while often criticized, is focusing on the activity as representation of human being, rather than on the cognition itself. It sees the activity as an extension of the cognition, that encompasses many aspects of cognition while putting an emphasis on the relations between subject-object. As such, the basic definition for activity is "purposeful interaction of the subject with the world, a process in which mutual transformations between the poles of subjectobject are accomplished" (Leontiev, 1981) and subsequently that the theory "maintains that no properties of the subject and the object exist before and beyond activities" (Leontiev, 1981, p. 89). While adopted like this, activity can be understood as unit of analysis providing a uniting tool to understanding both subject and object and that, in fact, one cannot be understood without the other and without the knowledge of the nature of the relationship between them. From the perspective of human beings, Activity theory also emphasizes the importance of activity for the development of both subject and object and the relation between them over time. According to (Kaptelinin and Nardi, 2006), adopting the activity as a unit of analysis will provide us with a tool for for understanding both subject and object engaged in an activity-like relationship, something we would not be able to achieve if we thought of them separately.

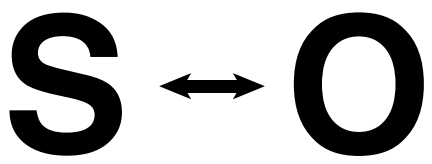

Figure 2.8: Basic representation of activity. (Kaptelinin and Nardi, 2006).

The notion of activity is central to the conceptual construction of agency in the Activity theory. Activity as such is always attributed to subject.

Subjects live in the world and "have needs that can only be met by acting and being in the world"(Kaptelinin and Nardi, 2006, p. 33). The interaction is then initiated by subject and thus the basic relationship shown in figure 3.1 is not symmetrical. The asymmetry is, as the authors put it, given by the fact that subjects have in fact biological needs to act. Therefore it is this ability and the need that form a special agency exclusive to living things. Activity theory insists that this intentionality is at the core of the asymmetry for it gives human agency a special particular potency that cannot be found anywhere else.

Similar take on agency also has Andrew Pickering (Pickering, 1995) who also promotes the idea of asymmetry based in the intentionality and having insight into things that brings us abilities to plan into the future. Pickerings detailed explanation is illustrated on the example of invention of bubble chamber by David Glaser (Pickering 1995) where the non-human agency is emergent only in contrast with human practice. While there is no human activity or practice, this agency is practically invisible.

The refined and informed definition of agency that Nardi and Kaptelinin(Kaptelinin and Nardi, 2006, p. 242) offer us is based around producing an effect, or producing an effect according to intention respectively. Any tool or technology thus, albeit extremely complicated and autonomous such as Mars probe or rover (Ibid.) cannot have same agency as people, as those are the ones who produced it, programmed and thus sculpted the agency it has in it. Humans can develop their intentions and carry them out, something that is exclusive from other entities. The core argument for the asymmetry is that agency is based and includes both biological and cultural needs. Based on this asymmetrical approach, Nardi and Kaptelinin offer a typology of the agents (See table 2.1). This classification of agency offers some fine grain distinctions while others, for example humanmachine agency (Rose et al., 2005) or humanmaterial agency (Pickering, 1993) often

	Agents	Things (natural)	Things (cultural)	Nonhuman living beings (natural)	Nonhuman living beings (cultural)	Human beings	Social entities
Agencies	**Examples**	tsunamis, Northern lights, vernal pools, Martian rocks	speed bumps, sewing machines, teapots, adzes	grizzly bears, California poppies, truffles, protozoa	house cats, Dolly the sheep, GMO corn, Bourbon roses	Spinuzzi's traffic engineers, Miettinen's scientists, ANT's princes	World Trade Organization, Doctors without Borders, United Nations
Conditional agency	**Produce effects**	Yes	Yes	Yes	Yes	Yes	Yes
Need - based agency	**Act according to own biological needs**	No	No	Yes	Yes	Yes	No
	Act according to own cultural needs	No	No	No	No	Yes	Yes
Delegated agency	**Realize intentions of (other) human beings**	No	Yes	No	Yes	Yes	Yes

Table 2.1: Different types of actants and agencies. (Kaptelinin and Nardi, 2006).

propose scheme that is dichotomized.
It is worth noting that activity theory is sometimes being dismissed as esoteric, but its use in computing got some positive feedback and attention. Its main contribution for the field was that it helped to shift attention from the user itself to the activity. It broadened the scope of theoretical thinking brought into design. The center is not the user as such, but it extends further thinking about the trajectory of the activity that includes the user herself, but other elements that she is engaged with as well.

2.5 Actor Network Theory - Basic Concepts

Similarly to what phenomenology and activity theory did for HCI, I propose to urban computing design to turn towards the Actor-network theory as I believe it provides interesting alternative for re-thinking the organization of contemporary cities. The Actor-network theory gained its popularity during 1980s and 1990s through work mainly of Bruno Latour, Michael Callon and John Law. It is a rather radical theory that originated in Science and Technology Studies where it established an anti-essentialist position standing against differentiating between science (knowledge) and technology (artifact). Consequently, it tries to explain both material and semiotic relations between entities in the world through a few of radical philosophical concepts.

The actor in ANT, a carrier of agency, is termed actant (to differentiate from actor often associated with human beings).The concept of actant is a heterogenous mixture of social technical and cultural factors. Because ANT promotes seriously the agency of other than human entities, it can be anything from machine, animal, techno-social system and other hybrid

entities. These actants can form relations, associate and disassociate with each other. That means the actants nature is derived from engagement with other actants in the network, rather than by some outstanding substantial or essential qualities. The networks themselves can become or be seen as actants while they become nested in some other larger network They can be anything from things, identities, to inscriptions and relations.

The core concept, that, as I argue, is interesting for design approach lies in the effort to overcome the distinction between agency, actants and structure (therefore linking actor and network together in the name of the theory). The analytic approach that is often connected with the earlier stages of ANT (Callon, 1986; Law, 1986, 1992) and that evolves into the the advanced understanding (Law, 2002a,b, 2004), is focused on how the networks form, stabilize by overcoming resistance, organize, assimilate new actants and convert and translate them.

The latter version of ANT that transcended from STS towards more mainstream usage started occupies itself with generally diverging and more complicated question: What does the emphasis on technology bring to the ecological, social, political and economic or any other processes? How are natural processes of evolution related to social processes of transformation and even physical processes of negentropy? In an attempt to answer to these questions and challenges ANT employs interdisciplinary approach that bridges the gap between social sciences, philosophy, natural science and even design and art. ANT integrates the more descriptive or empirical methodologies with the more normative and practical approaches in order to understand but also intervene in the complex socio-technological systems and situations involving many stakeholders, actors and even physical scales. Philosophical inquiry testing the limits of our language and discourse, empirical approaches mapping the human and social actors and scientific and technological understanding of facts and non-human reality

are always integrated in the ANT holistic approach. This version of ANT is transformed into normative and ethical approach and position to issues of nature, technology and society which uses design as an practice that can integrate these various actors, scales and stakeholders in some scenario based methodologies and prototypes. The value of ANT is that is brings a better understanding of the actors possibilities and stakeholders perspectives and providing a framework for more informed discussions about the possibilities and the limits we face in our complex society vis--vis ecological, economic and political crises. This inspires new design ideas and solutions which serve almost as an experimental methodology and framework to understand which version of our future we want to take. The original concept of hybrid networks changes in later ANT into cosmopolitics and various notions of hybrid collectives especially in the work Latour - the development of the argument can be seen in his work through time (Latour, 1979, 1987, 1992, 1993, 1995, 1996, 1999a,b, 2000, 2004, 2005). The solution to any crisis simply lays in supporting the misalliances between politics, science and technology and making them simply more transparent and open for discussion by giving voice to all the stakeholders and actors.

The application of ANT to information systems offers itself as very obvious. These often very complicated techno-social structures involve technology, institutions and users entangled in mutual often very complicated relations. Hanseth Hanseth (2004); Hanseth and Aanestad (2004) emphasizes that the main controbution of ANT is that its hybridity offers a wide range of tools that can help us to understand the interplay between technology and its social context. The conceptual contribution, according to Hanseth, is the main one, but there is also other ones, such as research analysis on development and use of electricity from 1880 to 1930 (Hughes, 1987) or more recently Bennets work the analysis of blackout in USA (Bennett, 2005).

But how can ANT contribute to a designer of information technologies and systems who focuses on the city? Tatnall and Gilding Tatnall (1999) use the ANT to describe the innovation during implementation - according to them, every implementation of information system is inevitably some sort innovation - yet more in a social way, rather than technical way, i.e. while the design of the information system itself may not be necessary innovative from the point of view of technology, it will be innovative from the social point of view, bringing some sort of new possibilities to its users. This is what Tatnall and Gilding criticize on traditional approach to research of information systems - that they tend to focus only on the technical side of the innovation and omitting the social one.

This trend, it needs to be added, somewhat changed during last few years with a lot of effort on design of both information systems and hardware technology invested into exploration of affective and emotional computing, acknowledging the importance of emotional engagement etc. Yet in this stream of change we do not find many ANT based approaches.

ANT itself began focusing much more on politics and higher processes rather than the actual, rather philosophical fundamental questions. Yet Graham Harman (Harman, 2008, 2009, 2010) tried to bring the discussion back to these core questions. In Prince of Networks he both explains Latourean approach towards objects while putting his work to a broader perspective of many other philosophical approaches going back not only to phenomenology of Husserl, but also to empiricism, but traces the debate all the way back to classical Greek philosophies (Parmenides, Anaximenes). While reproducing this debate is not necessarily useful for this dissertation, I will focus on Harmans core argument in the book, polemicizing with Latour about Latours radical approach to understanding objects. Harman often proposes somewhat softer approaches that lead to concept of strong, object oriented philosophy. It is this core argument that I intend to use in

this thesis to propose a sort of innovative design approach to technology situated within city space.

To map the whole territory, we need to mention also French philosophy of 2nd half of 20th century, around Deleuze and Guattrari. Their work on relationship of technology and society itself is often somewhat compared to ANT. While their assemblages really in many ways remind us of actor networks, I am leaving this direction of thought open and unexplored, even though there might be some inspiration for other design approaches. Deleuzes ontology plays a key role in foundation of "new materialism" that lead De Landa (2006) that take the concept of assemblage to approach social entities vertically through various scales.

2.5.1 Agency is not Exclusively Human

Agency, defined in broader terms as the ability to act is usually, from the philosophers point of view exclusively reserved to humans. This prolific view lies at the roots of Cartesian modernistic dichotomy of body and mind, where the first is seen as similar to other living entities and the latter can be only found in humans. In Cartesian times the body is a mechanical device and consciousness is the special human feature. There is not action without mind and body is taken just a a biological machine, a combination of physical systems that are thought of separately from the body.

User centeredness is visible even in the design terminology itself. When we look at concepts such as design affordances there is inherent passivity that we impose on technology. Technology affords us to act. Can we shift towards active approach? Can we surrender willingly some of our freedoms and submit to for example agency of the community? Maybe not submit and maybe not surrender our control over technology, but we can design

technology in a way that will stimulate us. Not by refusing access to functions that we see as not being the rightest ones, but maybe in stimulating towards different decisions.

Philosophy then tries to understand agency in the most general sense of terms spanning the understanding over the previously mentioned. While technologies that we can interact with span across these levels too, from sensing brain patterns to communication with large social groups, there is a need for understanding at least basics of these disciplines.

Activity theory emphasizes intentionality as a difference in agency of humans and non-humans. But cant we look at it in a more distributed way where there is intentionality encoded to other techno-social actants too? That should potentially work, as removing part of the intentionality from peoples hands to tackle problems and stimulate them. The act of giving up intentionality will be intentional that is okay, but also it will create a new type of interactive systems that are embedded etc. One could probably argue that there is a great deal of problems with this approach such as dangers of slipping to social engineering.

2.5.2 Non-Human Agency and Nudging

The main purpose of adopting the distributed model of agency for my thesis is the possibilities that it gives to us, as designers to stimulate, "nudge" users in the real space. While nudging in traditional urban design means cleverly positioning physical matter, such as bodies of water, trees and other plants or walls and other structures.

Agency of technology has also a power to stimulate and nudge our behavior and reach into the physical space rather than just acting within the

information systems. Software is something that can have agency and act upon users that then carry out physical action in the physical space. The measures are indeed much subtler than those that urban designers have at hand: getting wet stepping into a water pond in the park created there for certain purpose is certainly entirely different from designing a mobile embedded interface that will alert you by vibrating and flashing and on top of that can be actually turned off. While we cannot opt-out from respecting the laws of physics, we can indeed opt-out from using technology and should such device annoy us, we can ignore it, switch it off or just do not carry it with ourselves. While this argument is valid, it only makes us focus more at the enjoyment, entertainment and stimulation of the user to make her desire the active participation and letting herself be nudges voluntarily.

2.5.3 Agnosticism, Generalised Symmetry and Free Associations

To understand how actants should be approached in the liminal space concept, the ANT uses a number of basic theoretical constructions to describe them as well as the relationships between them that are, as we said, both material and semiotic or social. Let's take a piece of software code as an example. For instance, while we might argue, that a code is purely technical sum of information written in a language understandable to the computer, it is undoubtedly social (Kitchin, 2011) as well, because it was coded by people with certain socio-cultural backgrounds[14]. ANT addresses this difficulty of categorizing by a stance which denies the social-technical divide and thus denies the actual existence of purely social or purely technical actants. It emphasizes the heterogeneity of the relations. (Latour, 1992) says that the question "Is it technical?" or "Is it social?" is basically wrong. Since we have to consider the existence of both, the right question to ask is which one of those is stronger or weaker and what are the relationships

between them. In liminal spaces, the technology, the humans and the environment all have agency and influence each other.

ANT uses various theoretical concepts that are helping it to treat both human and other actants in the same way, as a symmetric entities: agnosticism, generalized symmetry and free association (Callon, 1986). The first one means that we are obliged to be analytically impartial towards all the actants we analyze, no matter whether they are human or non human. In this manner, the Navinko research focused on bicycle itself, bicycle riders, the conditions for bicycle riders in terms of policies, urban design, history, culture and bicycle technology itself. Generalized symmetry then dictates to use the same vocabulary to all actants, not to favor the human ones, as our languages contain a large number of anthropocentric words. While we analyze the actual networks, none of the elements should be given any special explanatory status. For example riders in the Navinko case, they should still be treated as equally important as the bicycle itself. The last principle of free association requires us to abandon and eliminate all of the distinctions between the natural, technological and social. Callon summarizes the approach as The rule which we must respect is not to change registers when we move from the technical to the social aspects of the problem studied. (Callon, 1986).

It is also worth noting that in his later work (Latour, 2005) calls for abandoning the word "network" at all as he claims, that it has been overused, compromised and rather than helping us to understand, it often adds confusion into the analysis of problems. The "network" itself is not a real thing, teaches us Latour, but rather just a representation and approximation of the real relations, that are often temporal, fade away, arise. From this point of view, the network itself looks more like a visualization of the actual traces of the relations in between single actants: "a network is not made of nylon thread, words or any durable substance but is the trace left

behind by some moving agent. You can hang your fish nets to dry, but you cant hang an actor-network: it has to be traced anew by the passage of another vehicle, another circulating entity." (Latour, 2005, p. 129). Similarly, it is hard to see cycling as a sort of static "network" - cycling is dynamic, changing, sum of all riders that enter into the relations with the bike, traffic, other riders and leave them again in the matter of moments after dismounting the bike in the front of the office and leave the context of a rider to enter the one of a salaryman, a mother, or a university student.

One of the most controversial, yet inspiring arguments of ANT is that, founded in the symmetry between actants and their their equal ability to act, the agency is not exclusively human. There are obvious differences between the actants, yet from the theoretical point of view, there is no difference between an action carried out by actant human, technological, or other non-human. This "web"[15] of relations is inclusive towards all actants, nothing lies outside of the networks.
The concept of non-human agency is provocative for many theorists and academics, because it acknowledges the non-exclusivity of human that we have been enjoying for centuries. However, moving beyond dualism theories[16] in humanities with acknowledging the embodiment throughout philosophy, psychology and sociology, the idea becomes perhaps more acceptable. It needs to be noted that the human exclusivity gets re-interpreted somewhere else in the system. Simply put, if we were to quantify the agency could be quantified, humans would be probably in possession of most of it. Or in other words, while many actants can function in limited number of aspects, human can arguably function in all to certain extent. While this does make us special, it also unfolds the possibility for the making the relationships between actants (human and non-human actors) symmetrical.

To present an archetypal example, a piece of technology that we are used to interact with on the daily basis, we can focus on an alarm clock (Tolmie

et al., 2002). Dodge (2009) shows that before the actual buzzing wake up function have been recreated in software and integrated into a various devices such as mobile phones, it was first mechanical, than employed basic electronics and finally became software . It closely followed the development of technology throughout the history, as we can see on figure 2.9 that I repeat for clear understanding.

Figure 2.9: A two alarm clocks from different eras of history. Westinghouse electric, mechanical alarm clock (1), agency outsourced to mechanical system connected to electrical grid. Digital electronic alarm clock (2), agency outsourced to digital, often radio-controlled system. iPhone alarm clock (3) with familiar setting, but running as software feature, agency outsourced to companion device with universal capabilities. Images - archive of author.

The actual approach we have is that we tend to believe that it works and

dont question its ability to wake us up[17]. This belief in technology that we have has been nurtured trough generations using the alarm clock that became the archetype of a device that basically just works and became the part of our daily lives and we outsourced the responsibility for waking on the alarm clock completely. We expect it to work and very few people actually are afraid that the alarm clock will fail.

It is a typical example of offloading our wake up agency to a machinery, that evolved from a physical thing to a piece of software, that inherits this archetypal understanding of it. This belief is actually very leap of faith like one. We can imagine to certain extent how alarm clock works, but the truth is that vast majority of people have no idea how exactly the technology works. The engineering is equivalent to a magic, that governed lives of people until the modern times. In the present world we believe in technology and we give up certain parts of our decision-making to it and let ourselves be stimulated (such as in case of waking up) to certain action.

Now if we step away from the problem of waking up and re-focus on much more advanced and complex problems we face in our everyday lives in cities, we will find out that there is not so much technology at work that would stimulate us towards certain type of action. The reasons are various, but one of them is the ambivalent fear of technology, that we share together with the belief in it. The same way that people of medieval times feared and admired the gods and magic, the same way we fear the technology today. Privacy issue, for example, is one of those. While there is a lot of in-depth debate on this issue, I would like to use it just as an example without going deeper in it. The fact is, that we get the irrational fear of being controlled, watched and often harvested for data.

The more advanced examples of non-human agencies that are often given in the literature (Knappett, 2008) are flying a passenger plane[18] from point

A to point B. While the focus is on city and urban experience in this thesis, it is possible to rephrase it as traveling from point A, Shinjuku station, to point B, Shibuya station, by train. Now it is possible to imagine how many things need to simply work for such thing to happen. First of all, the whole train system has to have a supply of electricity. This itself involves agency of many other actants, as Bennet shows us on the example of US electricity grid (Bennett, 2005). Secondly, the technical equipment must be working, or serviced while broken down[19]. There is a contracted company that does the servicing. Then there must be staff in the station and conductor to operate the train. The tracks between the station must be clear and there must be a green light everywhere for the train to be able to pass to the next station. Stepping one level down, it gets even more complex[20]. The station itself consists of different devices and appliances and systems. So does the train, the signal system, the tracks. As Heidegger taught us interpreted by Winograd and Flores (Winograd and Flores, 1986), the breakdown of a thing, or a software system, allows us to see many things on the"inside".

Such breakdown[21], in the case of train system in Tokyo, is an interruption of service due the various accidents or malfunctions. Probably the most prolific one here is a suicide. In such case, the train system is stopped for certain amount of time and consequently struggles with delays. Researching the "anatomy" of the suicide in a separate paper (Rod, Graham, Gibbs 2011), we also described another effect of distributed agency, that of replication of agency in different forms. The breakdown of one system creates a different pattern in another, in this case in the mobile network[22], where usage peaks due to the necessity of communicating the breakdown and delays to the destinations of passengers, or just killing the dead time by interacting with various internet services.

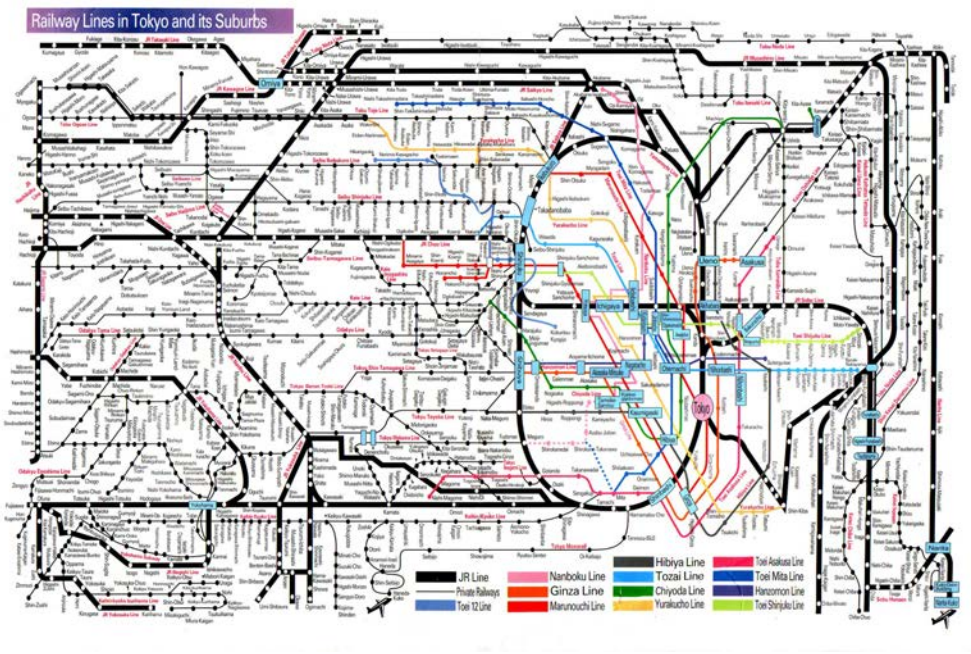

Figure 2.10: Tokyo train system. An example of extremely advanced actor-network with a large number of actants. Source: Wikipedia.

2.6 Case Studies of Projects Focused on Different Types of Agencies

I have selected some of the contemporary and very influential projects that demonstrate the approaches towards agency that I highlighted here and that I apply to design later. While these projects do not explicitly mention or focus on devising new approaches to agency, their functionality demonstrates that.

2.6.1 Natural Fuse - Humans and Plants

One of the areas that is attractive to design as well as quite well illustrates the argument for distributed agency is controlling energy consumption. While being discussed by many as a core challenge and behavioral

change that needs to be done to battle the environmental issues, there is also enough effort that is going on in the design field to help approach and tackle this issue. To illustrate benefits of technology that mediates and connects agencies of humans, nature and technology together lets look at contemporary design project Natural Fuse.

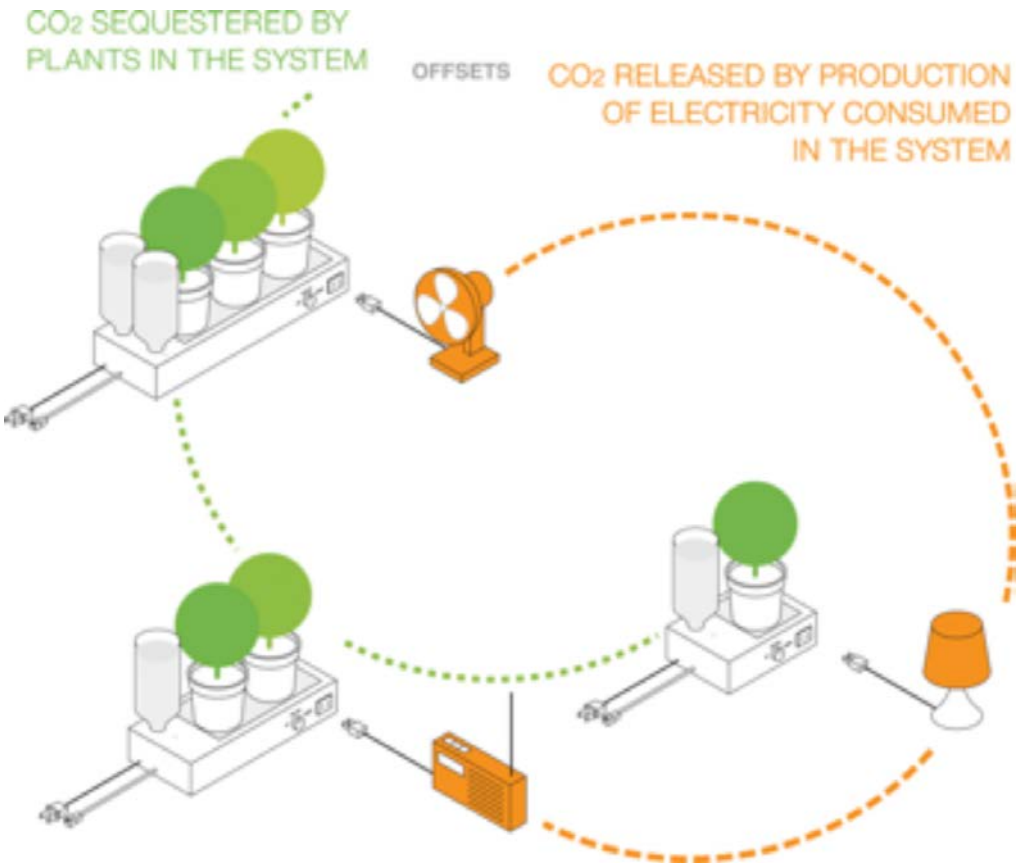

Figure 2.11: Usman Haque's Natural Fuse project. Source: Project site.

Usman Haques natural fuse is a project that integrates plants in between the electric outlet in the wall and any device consuming electricity. The actual plant then works as a circuit breaker shutting off the device anytime it consumes too much electricity. The trigger here is CO2. The production of electricity releases some amount of CO2 in the air (kwh is how much?) and the plant, on the other hand, consumes CO2. As far as the amount of CO2 coming from the electricity consumed by the device is smaller that

the amount of CO2 that the plant produces, the circuit is working. As soon as the device starts consuming more the circuit breaks. Now it would be probably unpleasant to have circuit broken at certain times, but the projects addresses that by pooling these resources for all plants attached to all outlets in the house. This is the first level of engagement that brings immediate response and attention towards the environmental issues. Yet at this level it is hardly something that would include community on the larger scale.

Haque therefore proposes to scale these technologies up to support offsetting the CO2 on higher levels - one street, city block, district or maybe a city itself. Sharing and participation is one of the Haques main concern, while one plant is often not enough to power even not very power hungry devices - "if you use an appliance that draws 4 watts, and there are 6 Natural Fuse units out in the community that are not currently drawing power then you can switch on your appliance at full capacity and comfortably offset the carbon footprint of your appliance by borrowing from the other units." The last feature that completes the system is the kill switch. Each outlet has a switch that allows user to choose between selfish and selfless modes. The selfless ones works in the way we described, disconnecting the power circuit anytime the whole community does not have enough CO2 sinking capability. On the other hand there might be times when you actually need power by all means. In that case you can use selfish mode that, in case the sinking capability is overflowed, kills some plant in the community. This threat that is out of hands of the actual user implements the important notion that the overuse of electricity will actually reduce the output of the whole network, as it starts killing plants. While as when people cooperate, the network can flourish and everyone can use more energy.

This interesting and innovative combination of consumption itself and the immediate feedback on it that is built-in should raise awareness of the environmental issues but also bring in the scope of how much plant force is

needed to cope with even very small anergy consumptions. There is an immediate connection between the consumption pattern and the environmental impact. The built-in fuse as killing plant mediated by what someone could potentially be seen as a drastic measure, yet there is an immediate connection between the act of overconsumption and death of a plant, creating a pressure on users of the network to behave responsibly and evaluate their immediate need for energy against the possibility of negative impact on the community as a whole.

Natural Fuse shortens and materializes the connection between nature and use of its resources by humans. Haques design solution creates a unique assemblage where plants ability to consume CO2 is directly tied to our consumption patterns - not individually, but adding the community aspect. It directly connects the agency of plants (absorbing carbon dioxide) with the agency people (consuming electricity) and technology (producing electricity while also producing carbon dioxide). It creates the the dynamic collective where meaning circulates between all the actants and people are directly stimulated to change their behavior. That way, we are not only responsible for our own plants, but also for the plants of others. The agency of the whole network then forces everyone to reflect continuously their consumption and adapt it to a sustainable level. The so-called "social-networking site" for plants that is part of the project visualizes the whole network.

While we think about the potential implications of this design, it could allow us to identify those who do not behave responsibly towards the whole assemblage harming both the plants (by overusing electricity and killing them) and consecutively also harming the users as their overuse reduces the capacity of the whole network. While Haque does not propose any practical solution, we can potentially think about some ways how to punish abusers - temporary short or long term limited access to the network is probably the easiest one. Similarly, there might be ways how to store

energy within a margin of immediate overhead to avoid the need to switch to selfish mode at all.

Similar project, yet less research and more design oriented is North House commissioned by Simon Fraser University, which is an actual project of architecture and designer focused on sustainable building and lifestyle as much as possible. While the physical design is interesting, the importance for this thesis lies again in monitoring the environment and sharing the actual statistics across the community. Living in North House means having very detailed information about the microclimate in the building, including lighting, air circulation and temperature control. This data describing the way you live are then shared with other members of the community and they can compete who is better in saving energy and optimizing their lifestyles.

Energy saving is generally a rewarding theme for thinking about agency. Researchers usually identify the social aspect as well as the importance of interface (Petkov et al. 2011 - ref. from Communities and Technologies 2011) (Karlgren et al. 2010). The interface has a power to provide immediate feedback as well as an overview of energy usage (p. 269) and stimulate the users to change their behavior. The suggestion of Karlgrens team is to pool resources together to reduce the load of the network (p. 271). Distributed agency - i.e. organization of people through the interface across some community (block of houses) can significantly reduce the energy peaks in the network and stimulate people to use less resources while still getting the hot water. While pooling energy between multiple households to cook hot water in one kettle might seem unfeasible, there might be other services that can work based on similar patterns and work fine.

McCullough offers theory of place, but not a theory for understanding the whole ecosystem - the city as an interplay of actants, different actor

networks. Not designing for a single network but connecting them both horizontally and vertically - communities and institutions are vertical connections, energy consumption and using power plants to control the production of CO2 is a horizontal connection of different actor networks that spans from production of electricity across power distribution, consumption, to the biological ecosystem and the fact that we can measure both how much electricity is consumed and how does that translate into CO2 and biological power needed to sequester that CO2. In fact, it creates a direct link between technology of production, social customs of consumption and combined effects on environment. It even implements emotional engagement as the actual fuse, where overconsumption results in death of a plant, which itself is a bad thing, combined with a fact that the plant is owned by someone else. While the interaction with this system is extremely easy, the conceptual construction is indeed extremely elaborate.

2.6.2 Pigeon Blog - Humans and Animals

The famous Pigeon Blog, officially called Interspecies Coproduction in the Pursuit of Resistant Action is a project of Beatriz daCosta that merges citizen science with the agency of animals for the purpose of air pollution monitoring.

The artists have augmented homing pigeons with small embedded air quality sensors together with GPS logging devices and repeatedly let pigeons fly around places exposed to pollution around California that are not easily accessible for other forms of air quality measurement. The animals in connection with pervasive computing technology participated in citizen science project. They act as an autonomous collecting swarming nodes that fly around and gather data that human agents would not be able to collect otherwise. While pigeons fly around, stationary sensors measure the values only in their vicinity. The rest of the data in between the stationary sen-

sors is usually extrapolated by computer, often ruling out the possibility of detection of pockets of deposits of various pollutants. Pigeon can map the values during the flight continuously showing where there might be some microclimatic changes important for evaluation of air quality and pollution.

Figure 2.12: An augmented pigeon. Source: Pigeon Blog.

The results from these data collecting flights were later used to create an exhibition pieces inspired by the whole project. The results of mapping mashed up together with aestheticized pigeon artifacts create an interesting combination of technology, data, animals and human agency that aims to stimulate people to take action in improving our living conditions: "With homing pigeons serving as the "reporters" of current air pollution levels, PigeonBlog attempted to create a spectacle provocative enough to spark peoples imagination and interests in the types of action that could be taken in order to reverse this situation." (da Costa 2008).

PigeonBlog draws its inspiration from even earlier applications of technology in connection with animal actants, namely an experimental surveillance project that used pigeons to take photographs of areas inaccessible to humans. The aim that the design team had in mind was to stimulate social action around the air pollution and its health consequences, connect the citizen science and bridge it with social activism and create mutual exchange between situated human and animal actants. From the ANT point of view, PigeonBlog blog demonstrates how we can interconnect human and animal agency to stimulate and instigate social action through so-called citizen science. It shows a new way how to address environmental issues through innovative channels that combine agencies of art, design, science, technology and animals together.

2.6.3 Copenhagen Wheel - Cycling for Scientific Research

The use of low-level hardware monitoring devices for a community engagement citizen science projects is one of the big themes for other projects as well. Copenhagen Wheel (Ratti et al. 2010) serves as a bicycle component but at the same time it collects the data and then transmits it to the iPhone on handlebars to visualize it for a user: "environmental sensors ... located inside the hub ... collect information. [It is then] processed and used to power applications that relate to a cyclists health, community or the environment." Not implementing inter-species collaboration, yet focused on the community Copenhagen Wheel turns every bicycle into the small monitoring scientific station that goes around the city and makes every rider a data collector as well.

The distributed agency of riders collecting the data can be then seen as a map and visual representation where everything is polled and combined

Figure 2.13: Copenhagen Wheel. Sensor network and riding support. Source: Copenhagen Wheel.

together, giving us an innovative view on the city. The purpose of the project is specified in the paper as to stimulate people buying (e-)bikes and cycling further and more frequently, but also to aid in transport related policy decisions, that, I assume, can also happen on the personal level.

While the distributed, de-centered agency in Copenhagen Wheel may not be as evident, as in the case of the Pigeon Blog, it still engages in interesting re-appropriation of activity of cycling into weather and air monitoring. Through a closed feedback loop and sharing data with other, the rider can see what is ahead of him or her on the road.

Copenhagen Wheel presents one more interesting problem that we often have to address in the design: The interface of the iPhone App for Copenhagen Wheel is screen based and thus it is questionable how often and for how long can user actually see the data that are being presented to her. While this is no problem for the majority of the claims authors make, we can imagine the potential for problems when we demand rider to look at and check the screen of the device during the ride while her attention is probably focused somewhere else. Obviously, as bicycle riding in the city itself is not always continuous user can always have time to actually look at the screen of the device while she stops.

2.6.4 Amphibious Architecture - Interfacing the Fish

The last group of projects I would like to address in this part of the work is the one that focuses on interconnecting agencies through innovative interfaces. The prominent and very famous project discussed by the creator Natalie Jeremijenko in one of the pamphlets on Situated Technologies series.

Figure 2.14: Amphibious Architecture. See where the fish swim in Hudson River. Natalie Jeremijenko.

The last group of projects mentioned here, and also arguably the most conceptual one, is exhibit called Amphibious Architecture presented at Towards a Sentient City exhibition by Natalie Jeremijenko. As a part of the ongoing effort her team created interface that mediated the communication between fish in the Hudson river and New York citizens. The interfaced was made by a grid of sentient light beacons that were placed in the river and sensed the presence of fish beneath. The visitors could either watch the way fish move or they could stimulate their movement by feeding them and then watching their reaction mediated on the water level. While fish are generally scarcely visible in major cities (with Tokyo carps being an exception), this installation provided a possibility how to connect them with the city inhabitants on the conceptual level. While there is not any immediate semiotic exchange between them, the project still contributes to this thesis and the debate on the dynamic versions of collectives that can

be formed through situating technology in the urban environment.

Instead of treating the water as a reflective surface to mirror our own image and our own architecture, the project establishes a two-way interface between environments of land and water.

While these projects often employ technology, sometimes it is stunning how examples can be much more simpler that that. Fun Theorys Piano Staircase is designed enhancement to a staircase that was painted as a piano keyboard and at the same time played sound every time anyone stepped on any of the steps. Changing a mere walking up the stairs into something enjoyable and creative reduced the number of people taking the escalator that was right next to the stairs by 66 percent. While this is an impressive argument that we can use technology to stimulate interactions and nudge behavior, there i always a question what is the longer-term effect.

2.7 The Conception of Liminal Space

We still lack new concept of urban computing, therefore I would like to propose the "liminal space". Liminal space is a new type of public space that integrates the companion and situated technologies with urban design. Such space communicates with the entities that inhabit it and stimulates their actions. It is a space that reaches out to the entities that occupy it.

The "liminal" term refers to "liminality", a concept known to anthropology as something "in-between". We can trace the use of the term to Goodman and Goodman (1947), but also many other authors who refer to liminality as to something that represents transitional times, transitional rituals, or transitional places Horvath et al. (2009). The use of "liminal" in this thesis

refers to moving to urban computing applications that are active and have agency, influence users and transform their actions.

Liminal space dislocates the current structures. It is a re-organization of the public space. It is a state, when technology becomes active and transforms the public space into an active participant, that can reach to the human inhabitant in ways different from the established ones. It is a space where public screens of digital signage and private displays of mobile phones create one eco-system to distribute content. It is a space where Navinko servers push specially crafted sound set into user's phone when she gets out of the station she had not visited before. These locally specific sounds will help her to discover what is around her, stimulate to explore and tune in to a mood.

The liminal space is a vision of the city where the exchange of meaning between various human and non-human actants brings a radical change. It creates environment where people inhabiting the city are stimulated towards action by the active space, not only passively moved by the physical urban design. Liminal spaces are environments, where agency of the non-human is acknowledged as positive, catalyzing power that transforms the space. Liminal spaces are actively taking part in circulation of meanings, they are designed to be aware and enrich the experiences of their users through various companion devices.

To construct liminal space, a designer needs deep understanding of the relations between elements of the space, as they participate on constituting the experience. I propose to use Actor-network theory for its ability to describe and understand complexity of a city or its part. Cities are composed of many entities that often influence each other in ways that are not obvious. These hidden relations are something that ANT can help us discover, describe and then use for the design of technology.

Third chapter presents the concept of liminal space and the strategy how to design it using technology. As an example, I present Navinko iPhone application and also describe its theoretical foundations that present a model example of what kind of design we should create to achieve the ideal of liminal space.

The nascent concept of the liminal space is different from "Hertzian space" (Varnelis, 2008) or "datasphere" (Rushkoff, 2009, 2010) and "mixed reality" (Cheok et al., 2006,?). The former defines the sum of all bits in the space, as a "layer" that is determined by the clicks of the frequency crystals (found in almost all electronic devices) similar to "biosphere", or "noosphere". The latter is a field in technology research that focuses on overlaying user's view of reality with pixels. In other words, liminal space is a *design concept*, rather than a description of something existing, or a field of design research. Liminal space is a concept of new type of space designed to innovate the city environments, create a space that will circulate meaning between actants and actively participate in supporting and motivating their actions.

2.8 Alternative Methodologies for Evaluation

The traditional design research approaches use user studies to evaluate the designs. While this thesis also presents a traditional approaches like this, it also addresses and alternative, specific approaches to design that react on the somewhat more demanding situations of the liminal space projects. The reason is that simply these projects involve larger number or stakeholders, or can collide or clash with rules and regulations. While designing

for the complex assemblages of actants there is often both expected and unexpected circumstances that can prevent the prototypes from being tested, deployed, or even made. Liminal space applications are specific by the fact that they are often very hard to test in the "laboratory" and controlled environment. The actual conditions of the complex city space can hardly be simulated.

Every experimental design set in the city can often lead to difficult situation when it needs to be tested. Problematic situations can appear because of the difficult and complicated physical and semiotic structure of public space. Conflicts with laws and regulations, differing local conditions influencing the experience and problematizing the design. Navinko had such problems with headphones, which demonstrates how is the public space governed by different entities with different agencies with various stakeholders. The potential for innovative prototypes to get into clash is indeed quite high. While one can often approach the solutions of these problems with changes to the prototype, that can still allow the designers to proceed, sometimes the sacrifices to the design would be too big that it would render the prototype testing useless. These situations may occur due to the various reasons, such as policies and regulations that apply to the public space imposed by state laws, local governments or cultural customs. They can also be ethical and most certainly vary from one city to another, or from one country or continent to another. To address all of those without severely compromising the design and possible value of the user tests, various trans-disciplinary approaches can be assumed.

Similar situation happened to Navinko, due to the regulation of headphones use on bicycles. Facing such problem that threatens to render the design untestable, it had to be solved different way - in our case we used bone conductive headphones that were not covering users' ears. In such case (even though the design, in the end, must serve the devised purpose, there

is a space opening in experimentation with public space, that allows for choosing a different vehicles, such as in our case, art exhibitions and performances. I argue, that in case of issues with ethics, clash with public regulations, or other fundamental problems, it is legitimate, or even desirable, to find a solution without compromising the design and while giving as accurate impression as possible. In the case of repositioning the design as art, it is possible to tackle both the ethical and / or regulatory issues. It is somewhat socially accepted and rooted in our culture, that art can be provoking, can breakout from the common social conventions, can challenge and question social order.

In a similar matter, for the user test presented in the later chapters of this dissertation, I had to choose alternative methods for testing, as traditional methods were not applicable. Technologies aimed at urban space need to be tested in urban space, as it plays a role in construction of the user experience. For that reason, I decided to use "cued-recall" method Bentley et al. (2005) initially developped for using computer games and that was later used in media art (Costello et al., 2005).

In both cases, the core of the research method is interpreting the data recorder by the observer with users' participation. In engineering, this is undesirable, as confrontation with the data might influence the users' interpretation of their own actions. While researching emotions and affection, however, this method proves to be useful in uncovering users' motivations, affectional perception and decision-making processes.

Using these non-standard methods in traditional engineering disciplines might be unacceptable, however, in design it seem to be becoming necessary. Repositioning design as art, however, also brings revision of roles. Users are often not real users, they are rather an audience whose reaction to the exhibit (design) must be observed in different ways than the

direct experience with using it. This fact calls for a repositioning of the traditional testing categories as well as for solving impossibility of using traditional evaluation methods. Audience can be interviewed about the impression they had about the exhibit, yet it is obviously impossible to get from them a real data about using the design, since they either observe the design (in the case of exhibit), or observe someone else using it (in the case of performance). It is possible though, to demonstrate the issues and stimulate a discussion about the with users. This can very often lead to surprising results.

Similarly the cued-recall also changes the role users are put in. They are becoming part of the design process and while reviewing the results, designers must be careful how to work with users during the interviews.

While Navinko had a problem during one exhibition and performance with using the headphones on bicycle and the performers decided to position themselves as artists and embrace the risks that come with it, the response was very positive. In case of ethical issues, it is probably more appropriate to use some piece of design or the design itself, letting to explain the story that surrounds it. Consequently, the test subjects that volunteered to participate were informed about this and were asked to wear bone conductive headphones that interfere with hearing the surroundings to a lesser extent.

Chapter 3

Liminal Space - An Alternative Vision for the Future Arrangement of City, Technology and People

3.1 Approach towards Urban Computing Based on the Notion of Liminal Space

Liminal space[23] represents a vision of an active urban space where technology plays strong role in stimulating, motivating and shaping peoples' actions nudging them into making choices aimed towards certain goals improving the life in the city: healthier lifestyle, sustainability, active participation on community life, or, more profanely, entertainment. Liminal space arises as an interplay of companion technologies we carry around everyday with us and local situated technologies embedded in physical things that extract data from the urban space. Liminal space builds on Actor-network theory to explain the relations between city, technology and people. A building, block, or neighborhood are promoted to enter a more balanced dialogue with humans through acknowledging that they have an ability to act, rather than being just a passive "victims" of users' interactions. Navinko, an iPhone application designed and developed by a small team of students, features some basic elements needed to achieve and instantiate the vision of liminal space and works as a design artifact that represents

this concept.

Figure 3.1: The view on Shibuya crossing. A rich, suitable site for developing early prototypes of liminal space applications. Image by author.

Companion technology applications transform data from ubiquitous sensing and situated technologies spread in space into nudges[24], an impulses transmitted through the embedded interfaces that instigate and shape people's behavior. Such technologies, in other words, can *act upon* humans, making them aware about their environment beyond physical human senses and limits of the spatial of the senses. Navinko, a design experiment based on basic principles of liminal spaces, aggregates all the places a user visits within Foursquare, and then transforms them into a soundscape and embedded interface based on headphones. This soundscape stimulates people to explore the city by playing sounds creating the impression they come from a certain place. It nudges people around the city space to go visit places that they have not visited long time, or that are favorite places of their friends. Besides sounds, nudges are represented in various interfaces

as alerts, sounds, vibrations or smells.

The theoretical explanation of liminal space builds on Actor-network theory and explains agency (an ability to act) between actants (the elements participating in exchange or interaction) as mutual and the actants as symmetrical. Within this theory, there is no differentiation between a technological device and a human, as they *mutually* act upon each other and thus are seen somewhat as equal. The agency is represented as data, and thus can be used to stimulate humans. This stimulation makes liminal spaces more engaging and promotes the interaction between elements of environment and users. It is a response to a search for new ways how to transform city space that we live in into exciting, exploratory and holistic interactive experience. In this manner, I proposed to use generative music in Navinko sound interface rather than voice commands we are used to from traditional navigation systems. It is a space that is actively participating on the exchange of stimuli between the entities that occupy it, be it living humans or non-humans.

Liminal space combines large amounts of data collected from within the space and connects to people through stimulative interfaces. It rewards[25], for example, citizens with discount or other reward in the physical world in selected restaurants while walking to the dinner rather than driving a car. A discounts on health insurance while people walk daily more than certain given amount of steps and order healthy food in restaurants, or when they go work out in a local gym. Liminal space encourages and stimulates users towards long-term goals, such as improving living conditions and experience of everyday life in cities.

Technologies embedded in space aggregate data from thousands of sensors about the microclimate, while companion technology can process these data to guide users through the city to avoid noise, pollution or just crowded

streets. The interface seamlessly interacts with their bodies, without imposing any additional needs on their interactions. To fulfill this vision of the liminal space we need to connect two existing approaches - a local, situated technologies residing in the space itself, as noted by Haque (2008), and innovative interfaces that will support stimulating and shaping peoples' behaviors by making them closer, an effort presented by Steinert (2010) or Rekimoto (2011). The situated technologies provide very important link with physical space, while the personal, portable and embedded technology stimulates the human users, nudges them and informs them, updates, alerts, helps and motivates.

Navinko expands the experience of Foursquare locative application with connecting the data to the companion audio interface. The similar shift that happened with the location as a type of data that got widespread, will happen with other sensors as well. Liminal spaces will thus become a synonym for new organization of cities where spaces are actively participating on shaping the lives of their inhabitants, rather than being just passive, inhabited and occupied structures with data infrastructure weaved in them. The data and the interaction with them will become *integral part* of the liminal spaces.

The liminal space integrates McCullough‘s various scales of environments. McCullough talks about different scales of places and the the need of technology to “adapt to our intuition of being in a place, give us a sense of scale” (McCullough, 2005, p. 142). In liminal space, the scales start to blend, as the technology inserts membrane in between them, transmitting the data, mediating and translating the meanings in between them. The goal is not the *separation* of the design for the scales, but design the stimulation of exchange *between* them.
Designing liminal spaces to reorganize our cities means inserting a thin layer in between McCullough‘s differentiated and enclosed scales of places

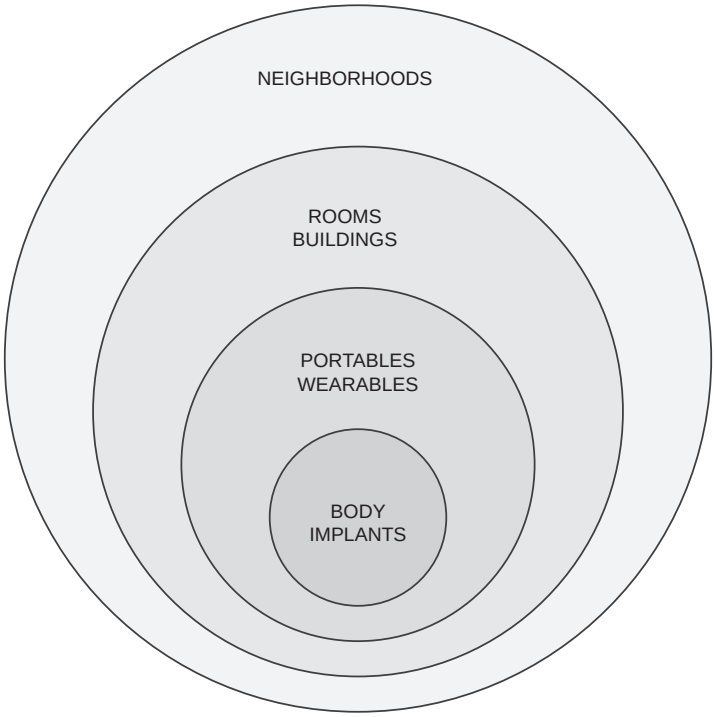

Figure 3.2: McCullough's diagram of "Scales of Place". McCullough (2005).

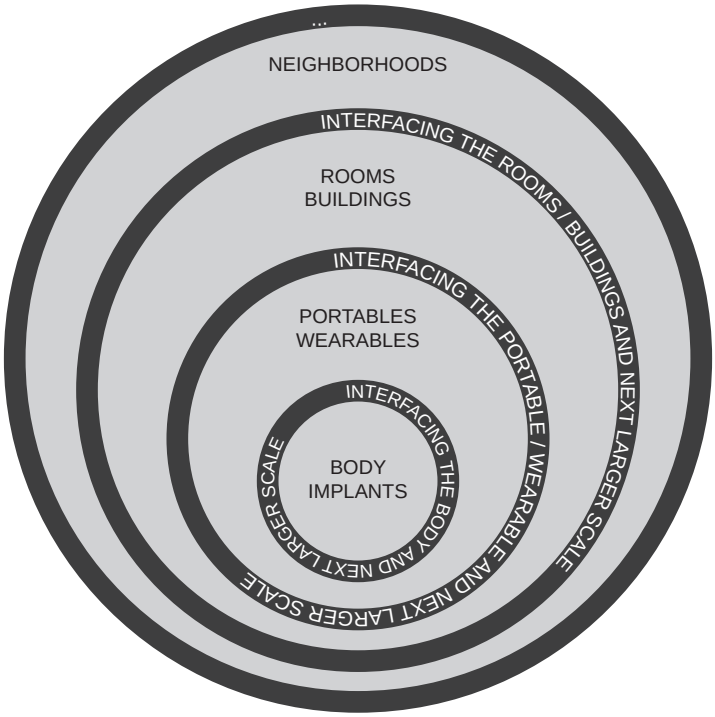

Figure 3.3: Scale of place visualizing the opening edges between the individual scales - "liminal spaces".

(McCullough, 2005, p. 142–144). This is where the human[26] agency meets the agency of the environment. In the liminal space, the non-human actants are given more power to nudge and stimulate, and data are not delivered on demand, but rather pushed to user in the form of aural, haptic or other interface. In other words, the companion technology, represented by a smartphone, already part of our everyday world experience (Ito, 2006) needs to be promoted to facilitate these new exchanges and redesigned to provide more embedded way of informing and impacting people through various modes of interaction beyond the basic one based on the screen.

The spatial organization of the scales remains valid, in the digital one the technology redefines the larger scale into a role of active, egalitarian actant that establishes partnership with other actants. The larger scale, that in the simplest instance can be a tweeting park, mall or a beach, takes up the role of an actant that participates on creating the experience and interaction. The differences between the user, environment and other elements start to fade, the importance of data circulating between them surfaces. The Twitter example again demonstrates this already with several home appliances being modified to tweet in last couple of years, such as: washing machines, coffee makers, dishwashers. The trend continues first with rooms or buildings and we will witness emerging less spatially defined actants, such as mentioned parks or beaches. The actants coordinate themselves through the exchange of data. Where McCullough (2005, p. 142) wants to differentiate technologies for the different scales of place (figure 3.2 on page 85), we need to understand the potential in exchange of meanings between the scales and design technologies that will transcend them, work in between them (figure 3.3), unite them into the new configurations, where the differentiation is overcame with symmetrical exchange (figure 3.4 on page 87).

Achieving the interplay and exchange between the scales was, in fact, desired by others, such as Finnish architect Eliel Saarinen who promoted we

should "always design a thing by considering it in the next larger context" (Saarinen, 1965). Saarinen emphasized the *connection* between the contexts, which are in fact McCullough's scales. His idea aimed at physical appearance of objects objects, while liminal reaches deeper, transforming the objects into actants. Digital technology gives possibility to create space where the scales dissolve, or where the technology works to transcend them. In a such way, an application designed to bridge the gap between the scales, between the limited mundane viewpoint of a regular person and a greater scale of a building, block or a city. In the larger contexts, where the numbers of actants is higher including those highly semiotical[27] the need for a meaning exchange is also higher. The user, approaching the reality from the human-scale view of the world needs to be made part of the circulation, informed, made part of the exchange.

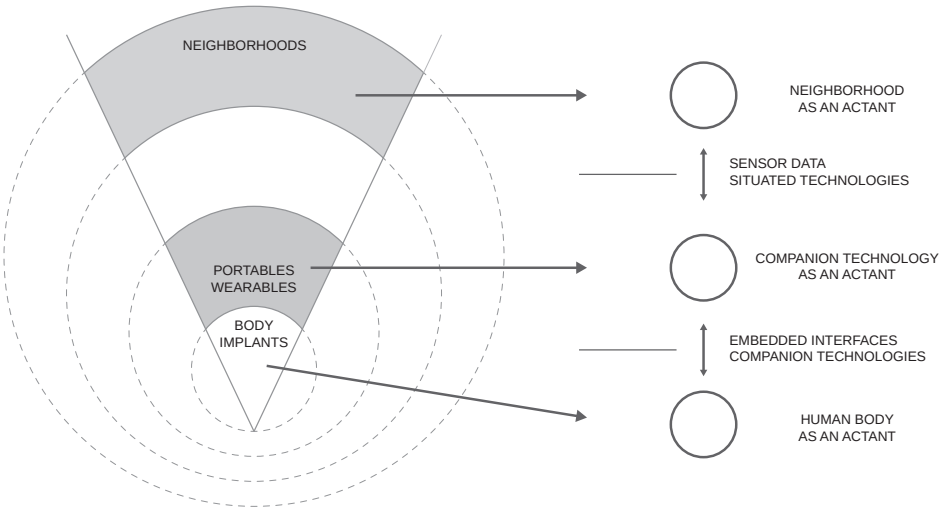

Figure 3.4: Scales transformed into actants and the circulation of agency between them.

To reach this mutual shift in the perception of actants and the design of technology, the companion devices need to reside closer and tighter to our bodies, being allowed immediate and always-on access to our senses[28], to stimulate our behavior in the line with longer-term aims and values.

Liminal spaces should actively stimulate user towards action based on the subtle specifics of the local attributes coupled with detailed understanding of user's behavior, needs and desires[29].

Liminal space is a vision that rethinks the way we approach urban computing design, using the Actor-network theory and realizing it in the practice by combining companion and situated technologies. Designing liminal spaces requires understanding them both theoretically as well as practically. Actor-network theory serves us to focus *away* from the traditional categories (Law, 2009; Whittle, 2008), such as activities, objects, users and other elements (all together called *actants*), and focus more on the space of exchange between them, the space of agency. The discourse of ANT has a large of body of literature and the scientific apparatus to describe it theoretically in the analysis. The practical part of the liminal space relies on the technology (Tatnall et al., 2003), the sensors that collect the data, infrastructure (such as mobile networks), that transports them, and actuators that either modify space or stimulate users. The joint of these two approaches synthesizes the core of the vision of the configuration of people, city and technology this thesis proposes. Accomplishing the liminal space vision requires paradigm shift in the design approach (Bardzell, 2010; Wright, 2010) that we currently use to design human-centered interactive mobile technologies for the city. Liminal spaces focus on the agency and its flow, without privileging any of the actual elements (such as users). Liminal spaces are represented by meaning exchange through embedded, seamless and passive interfaces that focus on exchange of agencies between the actants in the physical world, rather than just focusing on exchange of digital information[30].

The pieces of the technological puzzle are available, mobile devices of the present are pioneering the adoption customs among the masses with people using them in all imaginable situations during their daily lives and thus

they are paving road for new types of embedded interfaces that will couple with us more tightly. Secondly, situated technologies, local and context rich such as Jeremijenko's Amphibious Architexture (Jeremijenko, 2009), aim at embedding the environment and show us how the agency of various actants that can be incorporated to the circulation of meaning within the complex actor networks, such as pigeons helping to monitor the neighborhood to improve the environment in Da Costa's Pigeon Blog (Da Costa, 2008). In other words, this conceptual approach should help to produce technology that lives with the users and stimulates them from beyond towards the action within the physical boundaries of the space.

The body of this chapter explains the theoretical construction of the liminal space concept using ethnography infused by ANT, as well as it introduces practical description of the interacting technologies. Finally, I demonstrate both parts of the concept, the theory describing actants of Navinko - people, bicycles and the city itself, with a practical description of technical solution that I proposed based on the liminal space concept. In addition, it also touches on some parts of the design process that proved to be valuable in demonstrating how the public space and involvement of multiple stakeholders influences work of the designers.

3.2 A Theoretical Construction of Liminal Space

Actor-network theory's approach towards understanding the relationships and exchange of meanings between elements that are called actants is suitable for design of liminal spaces. It helps us to discover and understand what actants constitute the experience and how. That helps us understand and map the interplay of agencies. These two basic concepts of reality ex-

planation in ANT enter the relationships forming the actual actor networks. The actants are viewed through he optics of agnosticism, generalized symmetry and free associations, the theoretical constructs that describe them and the relations between them. I applied this to the design ethnography that resulted into the understanding of agency flows between environment and people on bicycles.

The use of ANT in ethnography has some predecessors, where it was used as a vehicle to study various complex systems, both technological (Elbanna, 2009) and others, such as healthcare or building construction related (Hitchings, 2003; Yaneva, 2009a). In this section I focus on how to present it in a way that would be useful to designers. It is primarily an inspiration to understanding complex material-semiotic relations between the people, objects, and other elements of space in the urban environment. This understanding establishes foundation for the concept of liminal spaces.

Navinko establishes links between people and environment that, represented by sound, can then actively stimulate the movement of Navinko users. This is the approach to design of technology that adopts and takes into account the material / semiotic relations while at the same time have more active agency to stimulate user's understanding of symmetric relations between elements that occupy physical space[31]. The user, nudged to a certain situation or stimulated to action through various types of interfaces. The action produces some sort of change in users behavior. The users are being pulled and nudged in the manner that follows their preset preferences, special situations and situation contexts. The importance of using information for stimulation of people in the near future was already discussed in depth (Hagel et al., 2010). I argue that the effectivity of this power of stimulative technologies will be mostly demonstrated through mobile technologies coupled with embedded, augmented interfaces.

3.2.1 Actants of the Liminal Space

The concept of non-human actant (Murdoch, 1997) is rooted in the Actor-network theory (Hanseth and Aanestad, 2004; Jones and Truex, 2005; Latour, 1993, 1996, 2004, 2005)[32]. The actant of the liminal space is an entity that participates on creating the experience with the urban space. They are social, technical, physical and human.

Actants enter into the various types of relationships with other entities[33], actants "mediate" and "translate". The actant can be a user (Bardini and Horvath, 1995), a building (Yaneva, 2009a), a metro system (Rod et al., 2011), a pigeon flying within the city bounds (Da Costa, 2008), a plant growing on the porch of the house (Hitchings, 2003), a city government that defines the rules that govern the space, the law that defines other sets of rules that govern the space, a club of people gathering to pursue the same hobby, a group of marathon runners training together in the park (Mantell, 2010), the the bicycle riders that gather to provide themselves with the increased safety riding together, such as in the case of Navinko (Rod et al., 2010). The group of cyclists that forms ad hoc using the Navinko app can claim part of the road, a lane or some side street and thus have a different experience riding together rather than within regular traffic.

The actants appear to be both material and semiotic. Let's take for example a group of cyclists consists of bicycles, humans, but also their personal intentions and shared interests, represented by shared cycling cycling time. Yet, bikepool can be seen as an actant itself, as it "acts" in terms of raising safety of the riders and reclaiming the space on the road. Similarly, a post office in the city is in fact a building that provides services to users, has a physical outlets (post boxes) around the city, as well as is governed by laws and regulations as an institution. As such, it is itself an actor network as well as actant. Figure 3.5 pictures some of the actants we can identify

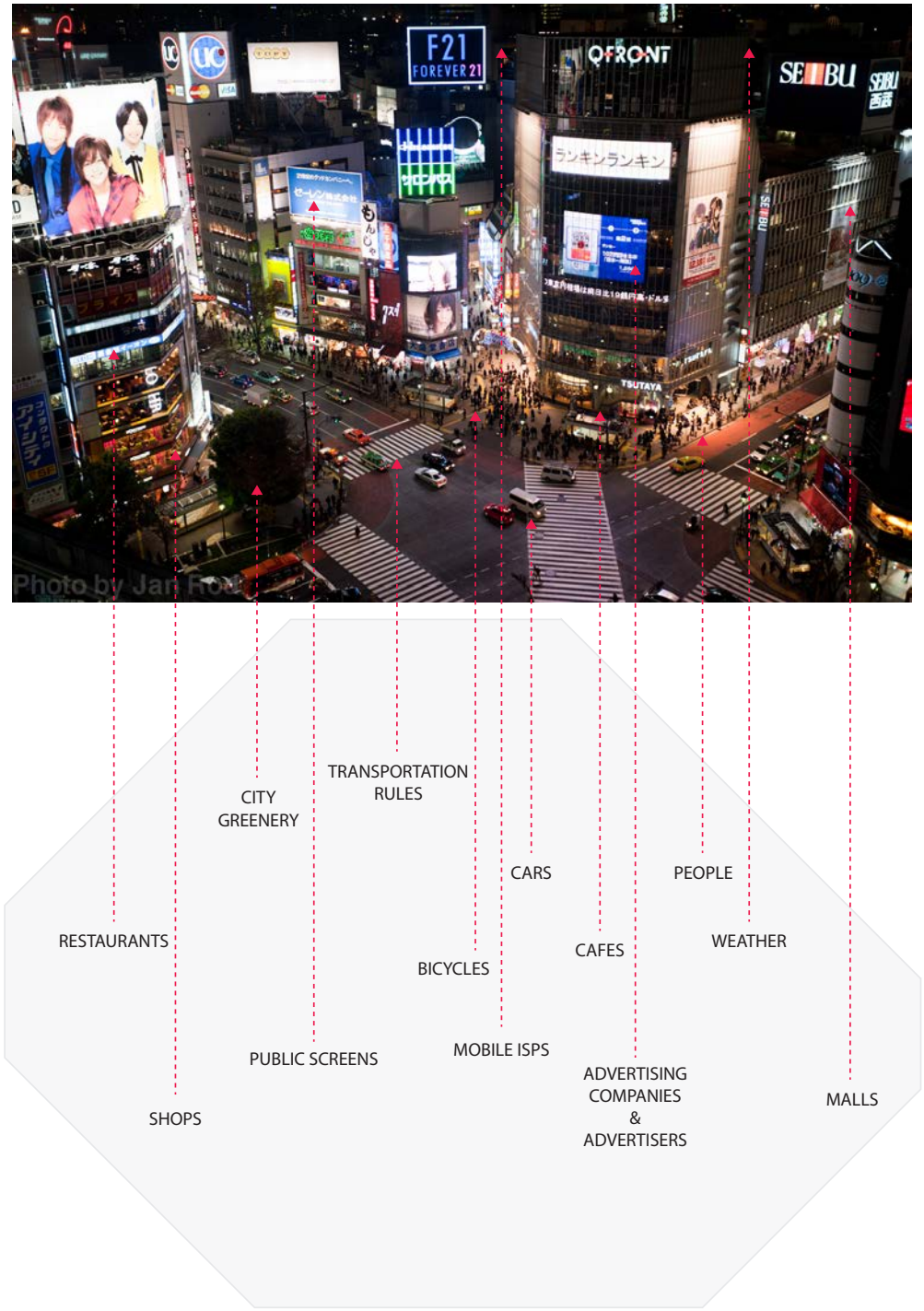

Figure 3.5: Actants of the liminal space examples. Photo by author.

just from one picture of Shibuya crossing. As we can see, this extremely urbanized part of landscape

For the purposes of understanding this thesis, all actants are thought of as equal and under such terms they should also be approached equally, e.g. there should be one set of terms used to describe them and no potential relationships between them should be ruled out up front. The free associations, agnosticism and symmetry between human and non-human actants puts human and non-human actants on the same level. Within such theoretical framework, all entities enter in different relations with others. These relations can be physical, sensory, social or aesthetic. Some will be reserved to humans, some to technology, different ones to nature, but we can hardly argue there will be entity that has none. Their interaction, the way they influence each other, or act upon each other, constitutes agency. The agency of liminal spaces is distributed one and emphasizes the importance of data and interfaces.

The relationships between the actants and the effects upon each other constitute the agency, which is represented in data. However, looking at it as a pure "data exchange" would be limiting. Agency emphasizes possibility of mutual *effects* of actants on each other, which can be represented in data, however itself is not agency. In the liminal space, the agency originates in mutual relationships and configurations of actants, the data are extracted and shared through the companion interfaces. Therefore, it is not a value, a number on the display of a smartphone within application that user runs to search the data. The technology acts itself and sends impulses to the user through the embedded interface. The data refer to something rigid and quantifiable, while "translation" through the interface refers to subtle aspects of the work of active interfaces (which are *also* actants) participating in reframing the meaning. The liminal space thus spreads the agency through the spectrum of emotional, social, material, visual, symbolic and

quantitative. Similarly holistic approaches gain some attention in computing at times, such as the ones presented by Norman (2006a) as Bodker mentioned in NordCHI (Bodker, 2006).

3.2.2 Blending the Scales of Places

The situated technologies show us, as a present avant-garde of the design research, the types of data we can work with. While coupled with companion interfaces that 'live' very near our body, the exchange between environment and actants / actants can vastly increase, they form the liminal space. The amounts of data in circulation are rising. These data allow the agencies of objects, people, things, elements and interaction between them to be captured. By connecting these data, making them meaningful, we create new exchanges, new configurations and possibilities for new types of interactions. Combined with the embedded interfaces, that by immediate and continuous access to our senses allow for stimulation.

With acknowledging the distributed agency of technology, urban space and people, I would like to ultimately point towards using it as a concept for unlocking the access to liminal spaces. Understanding the basics of ANT and adopting its stances leads us toward better understanding of how one can begin understanding the liminal space. It is the space where agency resides, the hypothetical space, where the agency flows from one actant to another and where, when enhanced by technology, can one design the applications and objects that are actively stimulating other actants, mainly the human users.

Re-thinking the design of companion interface based on sound for Navinko brings the locations into the ears of the user, rather than on the display of his device. This "channel" allows the flow of the agency that influences

the movement and activity of the users. Similarly, the associations can be done not only with locations, but also with objects, buildings, or neighbourhoods.

McCullough proposes typology of urban places and their scales for different types of ubiquitous computing applications. He implies that the ubicomp applications need to follow the specifics of the activities happening in the specific place, as well as whether they need to respect whether it is a neighborhood, public space, public building, private room or one's body. I would like to offer the alternative approach that places technologies into multiple scales and enables exchange of data in between them, effectively connecting them by inserting this ephemeral digital layer.

Previously discussed diagram of scales of places by McCullough (2005) is offering us a perspective that shows us the different scales and their demand for specific design solutions. Design for personal use on the level of personal device is different from semi-private use on the level of private building (which may or may not have some part publicly accessible) and also different from the technologies for public space. While McCullough's scales work well while approached from the human-centered paradigm, they start to break down while we start thinking of different configuration of them as actants. How do we design a system, that will stimulate users, make them feel interconnected and united with the space they found themselves in. How do we persuade people to feel comfortable nudged. These are the new types of the questions, we should be asking and focusing on.

While we start reconfigure it around different situations, we will discover that the actual important element is the "edge" between the different scales, based on the ad-hoc configuration of the actants. It is where the agency flows through to reach from one to another, within the context of the actual space. For example, there are differences in rules governing the space, in

the mutual position of the actants - person outside the building certainly expects the different types of interactions with the building than the person inside the building. Eliel Saarinen (1965) teaches us to always design a thing by considering it in the next larger context. Later in this subchapter I will describe how overwhelming is the number of contexts that we can discover in the city space. While architects are good at this understanding spatial relations and contexts, that allow them to design beautiful things, interaction designers are often left with more difficult situation at hand as software requires more subtle approach (Norman, 2006b). The design of technology often means very tight connection of physical and service design, while understanding vast number of related issues and at the same time allowing users to use the thing in open matter that can bring innovation. The typical example of that is Twitter, which evolved from group chatting into a full-fledged information network.

We have separate technological systems on each of these levels, but I argue we need to design systems that will work through contexts and through scales, mediating the meaning of data[34]. McCullough identifies protocols[35], but I argue there is something missing.

There is a need for technology that will work as a permeating layer inserted between the different scales of places and *adjust and re-shape* data into the form that will be appropriate for the scale and particular actant. Such technology can aggregate data from one actant, interpret them[36] and then communicate to another actant. The data generated by one actant can then be transformed into an effective nudge to the other actant in interface.

The most trivial of imaginable examples could be interconnecting already existing technologies. For example, public screens[37] in the train system and private phones. If we want to design a very simple system that will be effective and stimulate users (towards various ends) the private interaction

(lets say polling on an issue) can happen on the screen while some data can be displayed publicly with respect to the location in the station. For instance, a screen located in a place where people pass by demands a different design approach from the screens the people can see for some time in the car during the travel from one station to another. Lastly, there are private devices that people can interact with and that can display more private information. Such system, once built up, can connect agency of single individual, or vice versa, the system can be centered around the agency of some other actant - the train company itself or as an advertising system.

The number of combinations is vast and spaces for design start opening even in the simplest settings (figure 3.6). The people circulating in various situations enter, leave and re-enter again. Each of these configurations presents a certain opportunity for a design intervention that would interconnect the environment with people, by extracting data, creating channels to deliver in a stimulative and active manner. In the next section, I will describe in detail all of the phases of such process.

3.3 Designing to Create Liminal Space

Liminal space is an effort in transcending McCullough's idea of scales of place. Liminal space tries to focus on space opening *between the contexts* by constructing technologies that will transcend them and focus on the exchange between them. Where McCullough (2005) talks about the scales of the spaces that we need to design for, I argue, that the true challenge and *potential for the next paradigm shift* lies in designing with keeping in mind the special thin layer between the contexts and scales. The term "liminal" tries to draw the designers' attention to the transitional nature of the space in question and to its specifics. To put the notion of the liminal space into practice, I argue we should take a specific approach towards the technology.

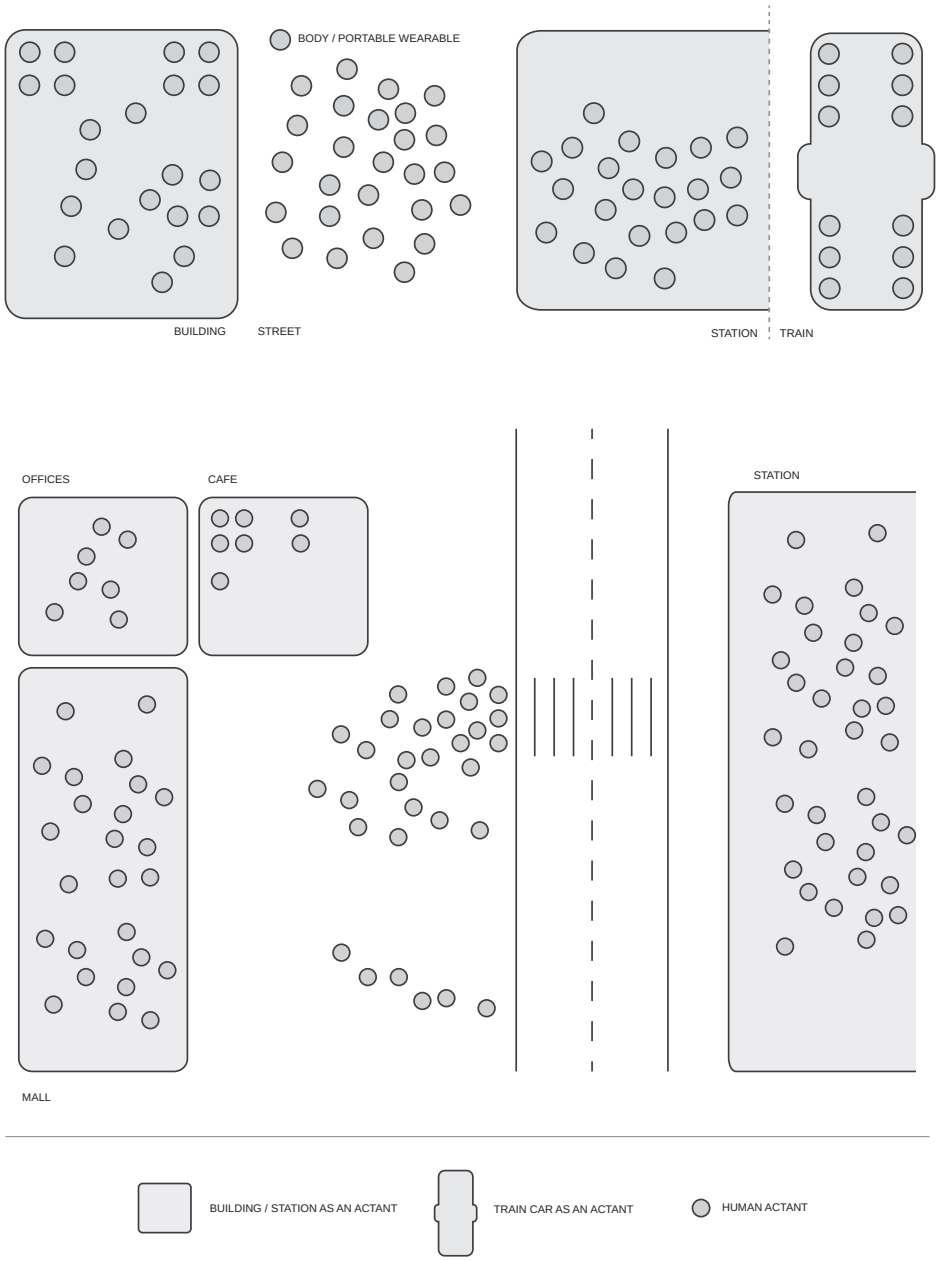

Figure 3.6: Different recombinations of actants and scales in public places. The buildings, train car and people enter into different configurations based on the design of space, each entity being an actant. Each of these configurations present an opportunity for design intervention. Photo by author.

To augment humans with more than just a channel to share the content typed on the keyboard of a device[38], we need to design technology that is stimulative, embedded and most importantly technology that would *enable us and stimulate to actions in the space*. Focusing on the agency, on the way that the other actants' agency is in the relationship with us and making it appear in the design, or focus on it with the design. By embedding users with carefully designed interfaces working together with technologies embedded in space, I argue that we can create technology that will circulate the meaning, mediate, and pull users towards acting.

In this section, I will try to sketch out the basic methodological approach to design of liminal spaces. The theoretical part of the practice uses Actor-network theory to reconfigure the basic presumptions we, as designers, might have about the configuration of space, society and the world around us in general. It is a tool to establish a specific mindset that must be carried further into ideation, prototyping and also evaluation of the liminal space design applications. Navinko application features exemplary implementation of the single elements of the liminal space in the form of companion audio interface, interaction with Foursquare - a database of situated information, and actively stimulates people to diverge from their set paths in the city while cycling.

The outcome, as I presume, should bring us into the era where physical and digital are mutually intertwined to the point it is not necessary to make distinctions between them. The era, where "being someplace digital" (McCullough, 2005, pp. 142-145), dichotomic distinction between the concepts, has given way to places that co-exist and are livable both digitally and physically.

3.3.1 Ethnography of Liminal Space

Actor-network theory uses three basic concepts for ethnographical descriptions and classifications of actants and agencies that they have towards each other. These three concepts describe how we should approach the actants while we research them for design applications. In other words, the ANT can help designers to analyze the site for an application / artifact of the design and form an understanding of the social and material interactions and relations that the actant, be it the site, user or artifact. As a demonstration of diversity of actants we can repeatedly take a look a figure 3.1 on p. 82. The relations and their strength then influence and potentially form the final outcome of the design process. In this manner Navinko addressed policy problems around the prohibition of riding bicycles with headphones. This shaped the design decisions, such as prototyping of mixing sound of the environment, or using bone conductive headphones that do not cover cyclists ears.

The inspirations for this research can be, for example, Yaneva's ANT-based analysis both of space (Murdoch, 1998) and also architecture (Yaneva, 2011), namely construction of the building from planning to moving in the first tenants[39]. On the other hand, I argue that this approach stimulates designers to be creative and to create types of applications, that are focused and organized around the actual links and connections between the actants, rather than the actual actants themselves. In Navinko, for example, we focused on streamlining the experience and focusing on the connection between the person, ever changing position in the environment and special qualities of sound and our hearing to produce the soundscapes. These soundscapes then motivate people towards exploration of the city.

As the approach of the ethnographer influences not only the interpretation of the observed, it also influences the focus. Tatnall summarizes in these

"two main ideas here: in many methodological approaches we think in binaries which often leads us to designate an entity as either technological or social, and then we attribute specific properties to that entity in order to explain its behaviour, thereby adopting an essentialist position. Studies that follow grounded theory often adopt this approach, but actor- network theory does not distinguish between the social and technological and sees properties as network effects rather than innate characteristics of an entity." (Tatnall, 2003). The design of information systems is techno-social (Tatnall, 2010), it involves both users and technology and the exchange between them (Lamb and Kling, 2003). In urban computing, there is one more element coming into the equation - the public space and all other actants that inhabit it. To be able to correctly understand it for the purpose of design, we need to understand the complexity that shapes the experience of the environment we intent to design for.

To illustrate the interaction and dynamics between material and social in the design of space Law (2004) gives us an example: "I am standing on a stage. The students face me, behind seried ranks of desks, with paper and pens. They are writing notes. They can see me, and they can hear me. But they can also see the transparencies that I put in the overhead projector. So the projector, like the shape of the room, participates in the shaping of our interaction. It mediates our communication and it does this asymmetrically, amplifying what I say without giving students much of a chance to answer back ... [and] ... the projector participates in our social relations: it helps to define the lecturer student relationship. It is a part of the social. It operates on them to influence the way in which they act."

The technical / social relationship is clearly visible when we analyze activities around cycling in the city. Bicycles are part of the landscape, as we can see on figure 3.7. Using bicycle in the Tokyo presents an interesting activity that brings together social and technical, in terms of interaction

Figure 3.7: Bicycles in Shibuya, Tokyo. Photo by Taro Ogino.

with the bicycle and the city through it. Social rules and conventions of the traffic coordination are represented in technological traffic lights. Cycling experience is influenced by cultural factors, such as whether you ride on the road or on the sidewalk[40], or whether there are cycling paths, such as in some European cities. Interviewing cyclists about their habits showed interesting facts: there are almost no people who would use their phone for anything connected to cycling. This is a different situation, than for example running, where Nike successfully integrated sensing technology to its shoes and offers Nike+iPod application in collaboration with Apple for several years.

In terms of interaction with a device, unlike jogging, a rider is unable to use hands to interact with the touch-based device while riding. Shifting visual attention from the road to display is also dangerous, also due to the average speed and maneuverability of the bicycle either between pedestrians or traffic. During interviews, however, some of the cyclists have mentioned

they would not mind to listen to something, if they could still hear their surroundings. This ethnography finding then translated into the actual design (see figure 3.8) in terms of explicit warnings to users about cycling and wearing headphones at the same time.

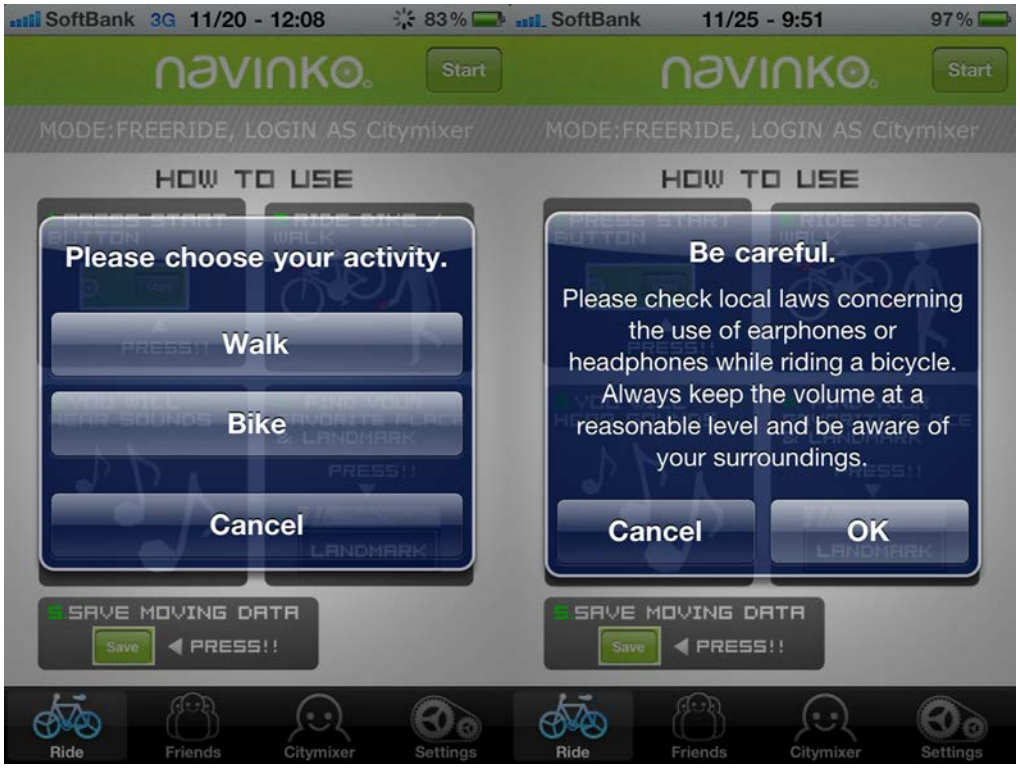

Figure 3.8: A selection of walking or cycling mode. After the selection of "Bike" mode, the warning is displayed. Photo by author.

Going beyond the interaction with the actual bicycle, we have to look into how cyclists use the city. The majority of cyclists in Tokyo commute the last mile, however there is a significant number of people who actually use bicycle as alternative transport beyond the boundaries of their own neighborhood. To pioneer innovative interactions, we have focused on cycling as an entertainment rather than cycling as a mean of transportation. While the enjoyment was also mentioned by participants of the survey as an important one, we decided to disrupt this space, rather than traditional navigation. It was also interesting that majority of people decided to not

use bicycle at all and walk or go by train instead if the conditions were not pleasant, rather than adapting their paths to accommodate to a different conditions. At the same time, we have found out, that the urban design and changing conditions in certain places influence route-forming and following to the point when people stick to those and not prone to explore, go off the paths to find new places and experience the city in a different way.

For certain part of respondents, the bike for them was merely a measure of making it easier to go to work / school / etc. It was activity that Gehl (2011) would probably classify as necessary and by no means social. Later we have understood that the routing and following certain paths / diverging from them will be a very important part of our design. Already at that point, we knew that we want to support bicycling as an alternative approach to transportation in the city, which is so heavily influenced by the extensive and extremely precisely working train network.

Reinventing cycling as a social activity and an activity that can be disrupted by technology was the largest contribution of the ethnographical research. Navinko embedded interface and the link created with Foursquare innovate the way people think about bicycle, it allows them to experience the city in a different way and reinvents cycling as an exploration activity.

3.3.2 Rethinking Applications of Technology as Actants

This thesis argues that designers need to reinvent the urban computing applications that treat city, technology and people as actants. This is especially effective at smaller, limited "sites", such as city blocks, single streets, Japanese central streets "shoutengai" (figure 3.9) concetrated around train stations, or shopping malls in Western cities[41].

Figure 3.9: Japanese shoutengai in Nakano-ku, Tokyo. Photo by author.

Technology that aims at smaller sites, rather than at whole cities or states, is easier to develop in small teams of designers with relatively limited resources. The site can also be connected to a specific events: large festivals or bigger scale exhibitions in cities, such as Tokyo Designers Week for which we have prototyped special version of Navinko that worked with shops par-

ticipating in shop exhibition and reinvented them as sounds based on the theme of the event: endangered species. The specific part of the city then offered aural experience that reminded jungle while stimulating people to walk around and discover shops and get stamps into their exhibition guide.

Lightweight applications focusing on these smaller sites are often easier to accomplish, because they do not involve too many stakeholders (Denning, 2011), can be put up quickly and, if well designed, provide satisfying experience. The important feature of these systems is that they share the data back similarly to democratization of APIs of internet services that brought a huge wave of new internet applications, mixing data together to create new functions[42]. In the same manner, the applications of liminal space create data that are open and can be shared, remixed and used in different applications to stimulate creativity, create new services or modify the existing one.

The approach emphasizing open data, a produce[43] of liminal space, is calling for services and applications that will focus on local areas and situations that occur between the actants and that will try to enhance, create or discover the new ones. Another aspect is the cultural one: the specific site oriented apps can focus on local, cultural specifics. In other words, "Shibuya urban computing" in Tokyo will be very different from "Lower East Side urban computing" in New York City[44].

The situated part of the technology often demands for a very specific approach, designing custom sensors, embedding the space with custom designed actuators or laying out wireless sensor networks (figure 3.11). To meet these demands, designers can turn to using resources of Open Source Hardware movement, or simply design the technology themselves based around ready-made platforms, such as Arduino, Gainer or other microcontrollers,. These platform enable designers to relatively easily develop

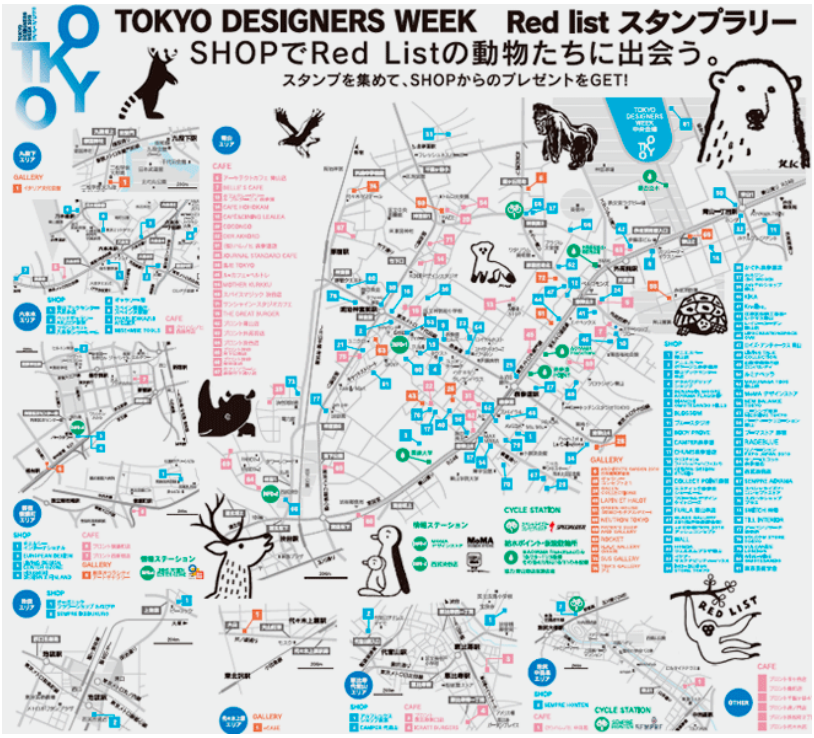

Figure 3.10: Specific site design of Navinko for Omotesando area. Image courtesy of Tokyo Desinger's Week 2010.

applications that use advantage of cutting-edge industrial level design of companion devices with open source hardware, both embedding it in the space as well as enhancing the smartphone experience by designing accessories. The importance also plays the easy accessibility of the platforms and programming tools for them.

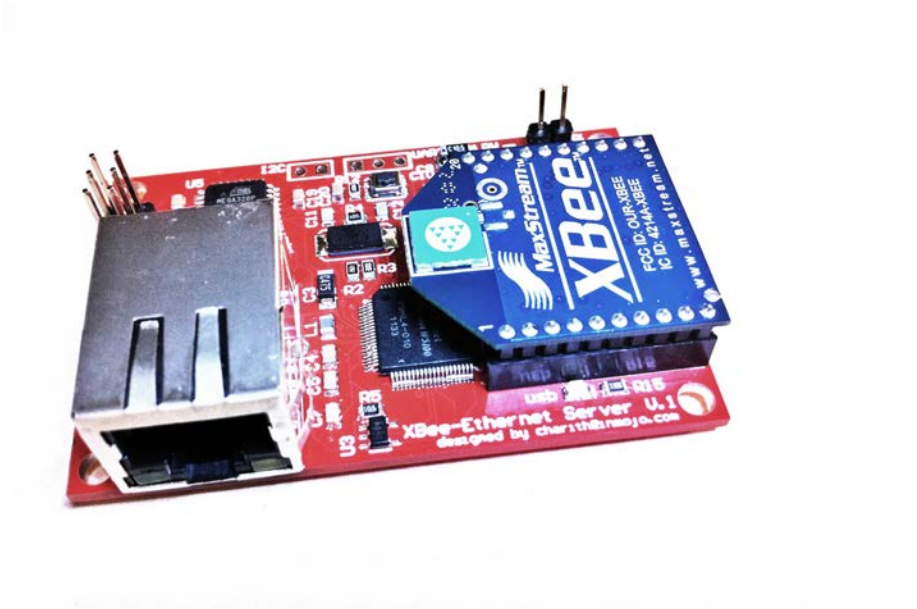

Figure 3.11: Internet-XBee Arduino compatible micro-server that allows two-way wireless communication with sensors and actuator in space via internet. An example of OSHW custom design technology for situated technologies. Designed by Charith Fernando. Photo by author.

As an example for an application that employs the combination of situated and companion technologies[45], let's take a combination of Twitter as an information network and platform for quick, broad exchange of information snippets, with local sensor networks and for example database of local shops, or other service establishments that can react to immediate changes in conditions (A cafe that run an automated Tweeting rain detector - "Free cup of black coffee during next shower"). One can then feel, interact and operate with and in space in a much more informed manner, with less information clutter than someone who is using the global services and is

overloaded with information that are irrelevant to the context.

The situation context emerges from combination of users's agency and the agency of the environment and allows to determine the type of information that are valuable to the user on the go. When it starts raining, my keitai [46] can know that I have no umbrella with me and automatically guide me to the place nearby where they sell them cheapest. In a similar manner, Navinko helps users in Tokyo to discover and explore city with embedded sound interface and generated soundscapes that inform people on the location of places that are interesting for them as well as users they are connected with. This can work well in a small area, where the sensor network infrastructure can be built rather easily and have a quick impact on the interaction of people with space.

The present situation of urban computing is being dominated with the design for humans paradigm (human-centered design). While it is focused on people to make interactions with techno-objects and designed services for them as easy as possible. This ecosystem of physical devices as handles for various types of services is neatly described in Kuniyavskys Smart Things (Kuniavsky, 2010). His book shows us the tight, but yet invisible links between products and the way they are constructed to work together. While the examples he gives analyze the industry-level products, they focus widely only on consumption. I argue, that with some alternative approaches that reach over to the actual design and production, such as open source hardware design movement, we can observe more of the invisible links between things and concepts, both material and semiotic. OSHW is great example how semiotic relations can become material. It is a concept, it is digital, it can be replicated and is a perfect example of Bruce Sterlings spime (Sterling, 2005).

3.3.3 Companion Devices - Handles and Interfaces

Smartphones dominate the companion devices[47], especially for their versatility[48] and functionality they implement[49]. Smartphones are the forefront of post-desktop where we carry our devices with us while they serve as handles for a vast number of services (Kuniavsky, 2010, p. 135-143).

Figure 3.12: Smartphones, the most frequent companion device and handle to various services, such as music, publishing or shopping. Source: Wikipedia.

The situation in the industry is very different from a small-scaled situated technologies that can be prototyped and developed in much smaller scales, faster and work in smaller levels of a building block, a building, limited public space (square or park). The potential to have higher impact on user lies in services built around custom interfaces, tailored both for the specific place and users - for specific actants, designed in a similar manner to the situated technologies applications I mentioned earlier.

The revolutionary impact contemporary devices have on our daily lives is very deep, as they change the industry[50] paradigms, redefine the ways we

interact with each other and the way we carry out mundane tasks, from commuting to dining. Before Apple released the industry defining iPod, for instance, there was no concept for selling individual songs, one could either buy a whole album on the CD or a single, but not a song, two or three. Amazons impact on book selling industry is somewhat similar, but there is one difference - before releasing the device, Amazon had the infrastructure already built (books marketplace, rights to them) while Apple had the device first (iPod) and added the service later. While we can say that both systems (the combination of device and service) are revolutionary, the foresight of Apple is in this case undeniable. We shifted towards a paradigm that is defined by networked devices that are handles to services.

These handles, even though they are mobile, we are used to using them and they bring huge revenues to the industry, they still have problems. Probably the biggest one is that they support only limited modes of interaction while on the go. That means when user is actually moving. The reasons is current paradigm of the interfaces that reign technology design is heavily relying on displays and screen-based interfaces. Looking at the efforts carried out various fields to enhance present displays focus partially on incremental improvements, such as increasing the PPI density or perfecting contrasts by employing numerous slightly different technologies (AMOLED, S-IPS, LED backlighting etc.). Even contemporary efforts to present proximity future visions very often rely basically on extreme enhancement of various parameters of todays screens, as do the designers themselves while often working exclusively within the screen based design paradigm. Simply put, what we can see now is pushing forward into converting every imaginable surface into some sort of display, in the best case scenario with touch input capability. One of the great examples is present Productivity Future Vision (2011) published by Microsofts Office Team. In this video, we are presented a multiple stories of people using extensive display rich environments, where the information seamlessly and fluidly pour from one display

to another, one in a see-through glasses, the other lying on the table. While this vision is attractive to many, it spanned internet-wide discussion and a wave of refusal from forward-thinking cutting edge commentators, designers and interaction design practitioners.

To build such technology and make it disappear from our perception field, I propose to focus on embedded interfaces, that would silently accompany us during prolonged periods of time and integrate better with us as well as our environment. The embedded technology is being extensively discussed in connection with embedding computers or micro controllers to the environment - such as for sensor applications, and networking them for data collection or analysis.

Such devices can be embedded also on animals (Da Costa (2008)), waste, milk, to track them and analyze the circulation of anything that can be easily quantified. However, there is a certain psychological barrier when it comes to augmenting our own bodies. While many times demonstrated on conceptual level, such as implanting RFID chips under the skin and using them as an authentication tokens, tattooing QR codes or many other surface-like experiments, they can hardly ever soon cross the line into the sphere of application. The highest technology that we have largely adopted and augmented to our bodies across the whole civilization will probably be a wristwatch.

Navinko embeds headphones, as it seemed the best strategy to achieve augmenting a human sense with a simple technology that people are already accustomed to. Embedding hearing outdoors and in the public space was pioneered for decades with coming of portable music players, notably Sony Walkman in the early 1980s (Haire, 2009). Until then, headphones were reserved for listening at home. This not only changed design of the headphones to make them more suitable for being worn in the public space,

but also created the whole set of cultural memes around wearing the headphones in the public, which we are still adjusting to until today. The music player evolved with the music formats from the actual cassette player, through DAT player, to MiniDisc technology to CD, but only with full digitalization of sound and its liberation from media such as CD allowed it to converge with a smartphone. The player itself became reduced to a piece of software that runs on a multipurpose device. The factor of embedment, however, was pioneered by the music player. It made us carry headphones around for hours at a time, do sports with them, use them while doing housework, walk in the city. The physical design of headphones also dramatically changed transforming them into low-footprint, in-ear buds that we hardly ever notice anymore. And while they do, in fact obstruct the hearing of the background noise while the music (or anything else) is playing, there is a certain level of "mix". These characteristics, i.e. people being used to wear them, they are socially accepted, can be easily handled and most importantly not having anything to do with vision formed our decision to use the headphones and generated music as an interface for Navinko.

Consequently it was important to decide which way to actually design the stimuli in a way that they will work and lead people rather than leave them confused and wondering as it often happens with new types of devices and interfaces. The important focus was thus simplicity and previously known metaphors (Lakoff and Johnson, 2003) that would allow instant adoption of the interface and let the technology disappear from our perception field, as phenomenology taught us (Dreyfus, 1992; Winograd and Flores, 1986). The need for seamless interfaces is especially important in mobile (Ahern et al., 2006) technologies, but also in AR (Dünser et al., 2007), tangible (Ishii, 2008), but also in CSCW (Moeslund et al., 2004) type of technologies. Navinko uses a sound and takes advantage of our abilities to percept the spatiality of the sound (Tuuri, 2010) - such as direction or distance and their fluctuation or change through time. While interacting with such

technology, at first, we might not understand the relationship between our position and the sounds, but once experienced for a certain period of time, we can start recognizing the metaphors and actually understand that the sound is tied to a place. In fact, we can go further than that and work with more complicated metaphors, such as simulated and artificially generated Doppler effect, to create an impression that there was something that the user just passed. This approach, as I argue, then leads to better acceptance and also to understanding of the interaction.

The sound or music can actually be used as a feedback designed for any other type of interactions, not only movement, position and motion (Hansen et al., 2009; Jylhä and Erkut, 2009; Overholt, 2009). In a similar manner, we can use other sensory input, such as sense or touch (Yamaguchi et al., 2010). These interfaces should though follow the same basic rules - be embedded in the sense that the user has continuous contact with it for continuous feedback (Vazquez-Alvarez, 2009), not being at mercy of decision to interact with it. In this manner, mobile phone in the pocket is not embedded, or only to certain extent of vibration feedback, that draws attention to things happening on the screen.

The decision to go with hearing was stimulated by the fact the I wanted to test my hypothesis that was focusing on the interaction part of ubiquitous computing in the city and the concept of "liminal space". My aim was to open the "liminal space" with the design, that connects digital infrastructure with physical space. That would go in hand with a specialized interface that would connect and maintain the flow of meanings between the users and the environment, shaping there decisions where to go. Thus, in fact, allowing users to access the "space" through interactions based around "metaphors" (Lakoff and Johnson, 2003), that exist in sounds and their understanding similarly to other types of sensory input.

These nudges focused on providing user with notion of relative location of the point in space. For the distance-telling we used variable volume, direction was represented by stereo mixing. The third and by far most attractive metaphor we decided to include in the prototype was the Doppler effect, or its digitally created version. We determined whether the user was getting closer to the POI or further and change the volume accordingly, while adding the frequency phase shift by changing the pitch of the sound digitally. With extensive testing in the lab environment we have determined that even slight pitch change calculation for multiple sources (20 and more POIs) presents significant loads on the devices HW and then decided to limit it to the few closest points. However, the problems experienced with the incorrect location reporting by the GPS module proved to be a problem in this case as well. While we devised strategy how to move on to tackle these problems[51] our design team did not have enough resources to prototype these functions, we therefore decided to limit the Doppler effect simulation to the proof of concept itself and put the plans for improving the function on hold waiting whether we will be able to get professional support for the project from some of the sponsor we were in contact with.

The sound-based interface with headphones was a key feature that allowed it to be truly embedded while augmenting the users hearing yet not obstructing their vision, thus only slightly altering the perception of the environment. On the other hand, it allows users to extend their perception of the space that surrounds them and creates a meaning exchange and circulation in an embedded matter.

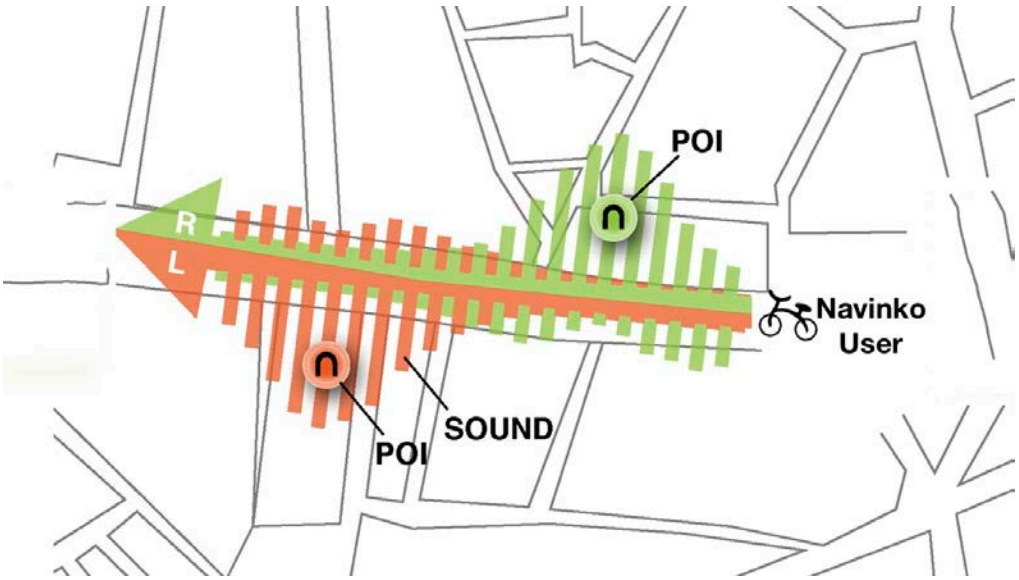

Figure 3.13: Simple drawing of the implementation of digital Doppler effect in the Navinko system. Illustration by author.

3.3.4 Situated Technologies - Sensing and Gathering Data

The second paradigm I analyzed in the literature review, situated technologies, is historically more entangled with the ubiquitous computing (Greenfield, 2006; McCullough, 2005). Situated technologies are focused on the interaction with a physical place, taking advantage of being tailored to its specificity and fine-tuned to the location both in hardware and software.[52] These configurations of technology specific to a place are more scarce, but we can predict they will grow in the near future significantly as well (Greenfield, 2006; Haque, 2008).

Situated technologies offer arguably larger space for experiments with interaction than market driven services[53] discussed in the previous section. The interfaces and interactions situated technologies are not tied to the paradigms of screen-based interactions and are very often embodied, focusing our activities such as feeding the fish in the Amphibious Architecture.

The widespread of these technologies is still to happen, but they are crucial for what I would like to propose within this paper: they very often allow for greater degree of user stimulation, because they, bringing new practices and having freedom of being designed to weave into the space itself, have a potential to stimulate users more. They are not being carried around, such as mobile device, they do not become an ordinary mundane experience of the smartphone in the pocket. Yet, they can benefit from availability to connect and interact with mobile devices. That means not to be main types of interfaces, but having some "outlet" for the data that would extend the reach of these technologies beyond the specific place and allow users to "take home" some part of the experience with the situated interface.

The strategy to achieve this new paradigm is theoretical approach that tries to support two important things - bottom up approach to building small ubiquitous computing applications in the city that will have what Greenfield and Shepard (2007), in a slightly different context, calls open joints - open exchange and access to data. These small-scaled situated services can work on the level of building block, a building, limited public space (square or park) - such as Navinko did with Shibuya for Tokyo WonderSite performances. The open joints (APIs, access to data) will make it possible to interconnect and create different types of combinations and configuration and allow the organic growth.

The central to this strategy are contemporary efforts, such as Open Source Hardware that democratize the technology, allowing designers to work with situated technologies in way that are much cheaper and more accessible. This subsequently can support of smaller size of situated technologies applications, limited sensor networks in neighborhoods, blocks, or public places, such as shotengai and malls. Platforms like Arduino, small-scale manufacturing like Shapeways, they all contribute to a possibility of creating embedded technologies, that will feature very few custom designed nodes

(using, for example devices like Arduino-XBee microservers. See figure 3.11 on page 108.).

The OSHW application that are relatively small provide alternative to the expert systems like large sensor networks. The expert systems that sense and control various mechanisms in the city are often already in place and have been discussed for the last three decades (Braca et al., 1997; Dorel et al., 2010; Grigg et al., 1976). They often comprise of vast number of controlled actuated nodes (cf. a specialized small scale sensor network / application by Haque, figure 2.11 on p. 65, with large scale application Realtime Rome, figure 3.14 on p. 119), that can communicate with each other - think traffic lights that adapt the intervals to the amount of automobile / pedestrian traffic. Or rail companies that operate trains within the city limits, such as JR, that fine-tunes the numbers of trains to the long-term statistics on the throughput of people collected from the RFID equipped gates at stations. While these systems work in a similar manner as urban computing applications, they are strongly separated from the reach of end user, that can see their effects in the city, yet she cannot interact with them. Should these systems become slightly open and transformed into those that are interactive, provide some functionality for the people of the city (i.e. are publicly accessible data) and open to interaction with other systems. They also do not have be primarily focused on optimization of such things as traffic, of transportation, as these systems are seamlessly weaved in to the fabric of the city and invisible to the regular citizen.

These expert systems provide a great example of backbone sensor networks that accumulate the data. Imagine if there was a possibility to build a local, specific versions of them and use the mobile devices, smartphones, to augment ourselves and create a way how to be alerted or informed automatically in cases where conditions are met. This is already happening with the location based services where the only context is the actual loca-

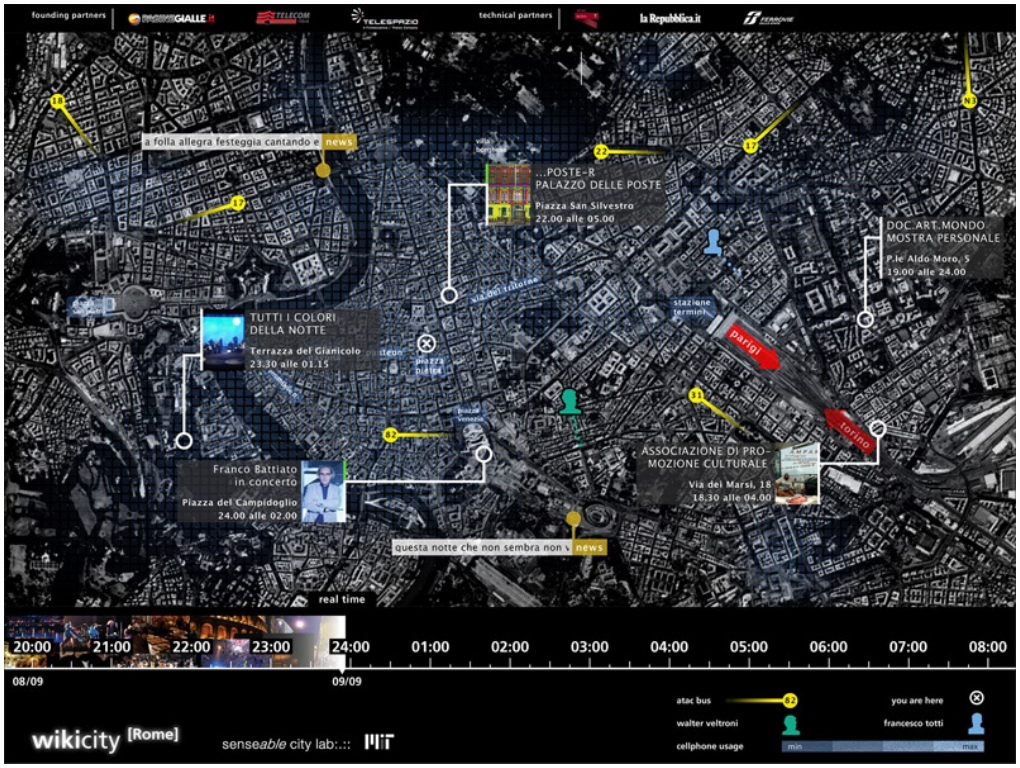

Figure 3.14: RealTime Rome. A large scale sensor network environment for the whole city. Image courtesy of MIT Media Lab.

tion of the user and affordances that are within his reach which can vary by proximity of public transport, availability of bike rental service or just having a car park right around the corner. This shows us, the part of the urban computing is focus on new types of data - data that can be generated within sensor networks, by movement of people, monitoring their choices, collecting the digital traces of their interactions (Latour and me). The amount of these data is raising as the information networks proliferate, databases interconnect through APIs, creating new recombinations of all the data.

The technologies embedded in space are crucial for creating data that later allow the interplay with companion devices. While configured together, both can work together towards stimulating users, instigating activity carried out in physical space and nudge users around. Both data from space and nudges can have many forms. In the same manner, Navinko combines data about locations and their types in city neighborhood with custom designed sound interface to change the way users walk and explore the city.

Interconnecting Navinko with another social service, location sharing oriented Foursquare was one of the core design features we envisioned that would support my argument of remixing data from different services through open joints, APIs, into creating new user experience. In the case of Foursquare, the main point was existing user base and very much exclusively screen-based interaction scheme in line within the traditional design paradigm when user takes out her smart phone, runs the app, checks in, sees the points received[54] and shares the checkin data either on Facebook or Twitter (or both).

The implementation of Foursquare API brought some challenges, as the system at the time struggled with a number of issues that were jeopardizing the experience with soundscapes. The biggest problem was data

duplication that resulted into an "information smog" of duplicated places, often with different spellings for names. Consequently, the high number of duplicate places was negatively influencing the Navinko audio engine that generated too many sounds at ones. The solution we decided to adopt initially was to limit manually the number of points that can be loaded and also the users can select the types they prefer to hear. We designed the filters based around the number of checkins the place has, which refers to its popularity and also based on the category. We also implemented functions for displaying only ones friends points or only points where a user checked in herself.

These filters proved to radically improve the experience. The filter based on number of checkins helped us to eliminate the overload and allowed us to select just the places that were popular enough to have meaning for the users. The personal checkin points then enabled users to generate the soundscape that was already based on their previous visits to these places and worked interestingly as a commemoration of the personal movement history. As the Foursquare app allows users to display their own history, there is no tool that would help them to browse it in a natural way that would augment their present experience with the city.

While the Foursquare solution has limits for large-scale production version, it is certainly successful for the prototype itself and it helped us to quickly see what the final experience with the application will be like. However, at present Navinko App does not support the other direction of data interconnection - that is registering landmarks from Navinko system into the Foursquare. The main reason for this is the fact that for Foursquare checkin user have to either choose existing place or create it, which goes against our fundamental approach that focused on as simple interaction as possible. Therefore at current version of the prototype implements only one-way integration.

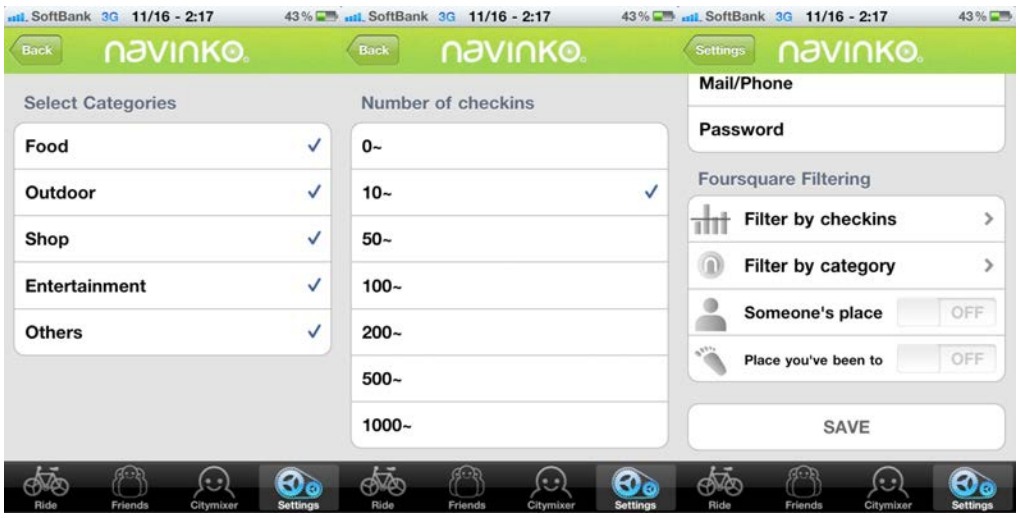

Figure 3.15: Screenshots of the filtering solution from Navinko application. Photo by author.

The Foursquare imported POIs are important in the beginning, but we wanted Navinko to work also as personal bookmarking service. Our idea was to make the mobile interaction as simple as possible, therefore we have decided to implement one click solution.

The reasons were multiple, but mostly because the interaction with the screen while walking is problematic and disturbs users from the focus on their surroundings. There are also other ergonomic issues - such as writing on the small keyboard to name the places, or even write while riding the bicycle, that is almost impossible. One click landmarking was an experimental approach that would split the interaction on two parts - the actual act of logging the locations with one click button and then filling out details later on the desktop computer, where the Navinko system connects to Foursquare again and suggests by comparing the NMEA coordinates the closest matching point from Foursquare database. In any case, users can input their own data and share with their friends within Navinko.

Negative	Positive
Situated Technologies	
Unknown interfaces, can discourage users	Unknown interfaces, can stimulate
Bound to location	Collects data from space
Limited reach	Provide context
Large number of stakeholders Demanding deployment	Data are accessible anywhere
	Easy to design and produce
	Accessible to design
	Often cheap off the shelf components
Companion Technologies	
Demands on design	Reside close to our body
Difficult and demanding to manufacture	Take on the form of a device for daily use
Limited expandability	Can tap into our senses
Controlled by manufacturers	Are intimate with users
	Collect data about our bodies
	Can use accessories
	Already (somewhat) established interaction paradigms

Table 3.1: Aspects of technologies of Liminal Space

Interaction with friends is not limited only to sharing the landmarks, but friends can also be "sensed". Navinko App logs position of each user and sends the data periodically (i.e. once a second) to the server database. While users become friends, there is also a function that retrieves these positions of users based on the mutual friendships and assigns different types of sounds to them.

While users then interact with the system, the static soundscape, comprised of the POIs and landmarks, is enriched by the presence of other people and their influence on other users experience. Our idea was initially let users use their own sound that would represent them, but due to the technical difficulties of this solution (there was no way how to permanently download the sound files to the device due to iOS restrictions) we have decided to go with the hardcoded sounds for the prototype phase. However, even the hardcoded sounds create an interesting and stimulating experience where the soundscape changes even though the user herself is not moving. In these situation, the experience of understanding of the presence of some other person is different from the interaction scheme where one is looking at the screen. The locations also updates continuously, therefore users can watch mutual movements that influence the soundscape generation.

This functionality is certainly fine for the prototype, it must be noted though that for the production version, there should be careful assessment of the privacy implications and there should be a more complex authentication procedures linked to this functionality to prevent misuse and satisfy the standards of users protection.

3.4 Beyond Navinko: Other Speculative Design Applications of Liminal Space Concept

Navinko itself is one example, of Liminal Space concept application. However, to illustrate other potential uses I would like to describe other potential design artefacts that can constitute Liminal Space. These speculative applications follow the same "guidelines" of Liminal Space concept as Navinko: they extract data from space, process them on servers and then send them back to users' smartphones where wearable and always-on embedded devices transform them into nudges stimulating users' behaviour towards changes.

The nudges, actuations of the actants based on the data, may sometime seem like small immediate inconveniences. Yet in general they present a large-scale positive change. Let's imagine a system that would mediate constant updates on air quality levels embedded in one's perception field [55] can have effect not only on one's movement in the city (desire to walk through places with a clean air). The differences in air quality in urban areas can be significant and immediately impact one's health.

Once we have data about the air quality (collected, for example, from smartphones of other users themselves), we can retrieve them to the smartphone (similarly as Navinko downloads Foursquare data) and use them to nudge user in directions of cleaner air. The data originating in single individually located sensors are then processed on the server to create an air quality map and to spot trends and changes in real time.

To nudge the users in the direction of cleaner air, let's imagine a wearable interface built-in into glasses frame. Using very subtle vibration patterns

users are alerted about air quality drop and gently directed where the air is clean. Such application is also re-purposing eyeglasses as haptic interface, rather than using Augmented Reality and overlaying user's visual field of view.

In a similar manner, we can for example use data from microphone to collect data about sound levels and use same embedded interface to navigate user in places with low noise levels. Alternatively we could combine the data sources to create a walk in silent environment with a good quality of air. Once such system in place, we can increase the granularity of the data and have the nudges activated based on combinations of the data to match users' specific demands and lifestyles.

Nudging as we walk is one example with many variations both in the way we nudge users (I have chosen the example of interface built-in into eyeglasses, but other approaches might work too) towards changing the way they navigate the city. It is like adding one more layer, attaching a new method of sensing and extending our perception field to be able to understand data that would not be available usually, or would be available at the cost of cumbersomeness.

Let's take a look at different applications than environmental quality. Another potentially interesting application might be supporting super-local knowledge and stimulate users to actively participate on life in their neighbourhoods. In such a hypothetical application, we should start designing away from using automobile as a main mean of transportation and stimulate walking (also for obvious health related benefits). In such case, a motivation to shop locally might be instigated by a local union of small shop owners, that could offer discount trading based on a mobile platform. A user, while deciding whether to go and go shopping to a mall by car, is nudged towards local interactions based on knowledge of others and di-

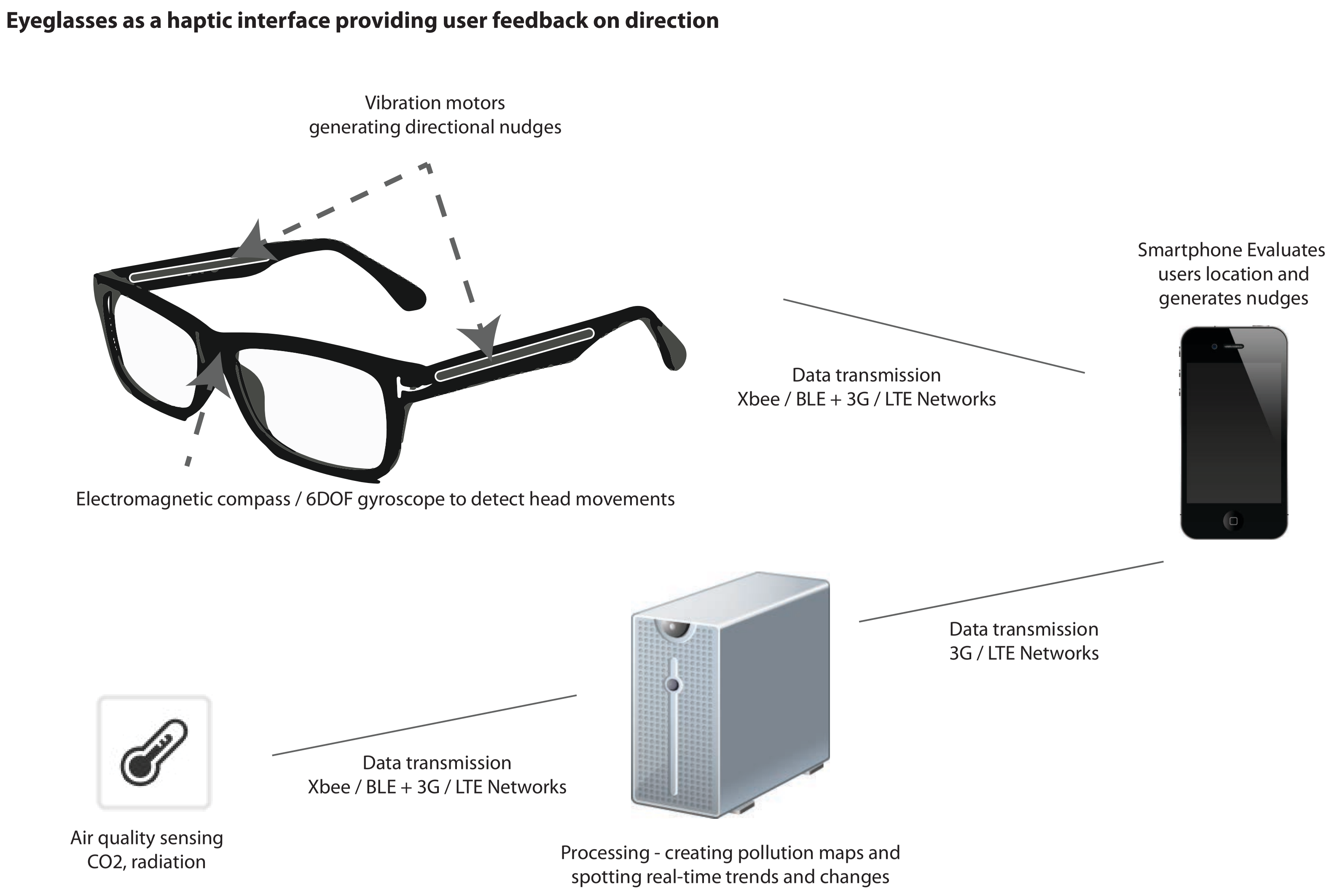

Figure 3.16: A sketch of speculative system to navigate users through the places in the city with cleaner air. Diagram by author.

rect interaction with store owners through the system. Secondary impact of such applications we can imagine is reduced a number of cars in the neighbourhood and increased pedestrian traffic. Sound interface, similar to Navinko would be probably most suitable for such design application with using audible clues, sometimes possibly combined with haptic based feedback.

There is obviously many ways of connecting and processing the data to change one's behaviour in other ways, such as decision making about public transportation, waste recycling, energy consumption, exercising, eating, shopping, to name just a few examples.

The liminal space brings a vision for the future of the city where the exchange of meaning brings a radical change that creates environment where people inhabiting the city are stimulated towards action by the active space, not only passively moved by the physical urban design. Liminal spaces are environments, where agency of the non-human is acknowledged as positive, catalyzing power that transforms the space. Liminal spaces are actively taking part in circulation of meanings, they are designed to be aware[56] and act.

3.5 Liminal Space as an Alternative Vision for the Future of Cities

Liminal space offers a vision of technology that plays active, supportive, embedded role rather than just simply being there. It integrates with our bodies and the environment playing on the vision of the early computing pioneers. Doug Engelbart dreamed of technology that is augmenting us, creates a tight bond with the human, technology that is alive with us and

directs us in situations when we cannot orientate ourselves[57]. Achieving this goal in combination with situated technologies is now closer. The aim is to create technology application that will look away from humans, rather than endlessly attending to them, try to stimulate them towards actions that improve their own lives as well as the environment. Liminal space is a concept where human agency, the agency of technology and environment are meeting to create a synergy between people and the urban space.

It might seems that this concept goes against human-centered design paradigm as such, however it only shifts the focus. The design principles stay the same as the human-centered design live within the liminal space as they are crucial to successfully design interfaces that will work. The actual experience with the technology may change in a way that it is more stimulative, more "agentic" (Steinert, 2010).

We have to bear in mind that liminal space is an interplay of situated and companion technologies that creates a city environment, where the distributed agency work as effective means to ultimately create a better, more entertaining and more livable environment. My argument tries to propose the combination the companion and situated technologies and draws upon an trajectory started by Navinko and other often experimental and artistic projects and design the services while maintaining open joints for sharing data created by OSHW and similar easily accessible technologies.The smartphones work as handles to the physical spaces and use innovative embedded interfaces to stimulate people. The configuration of objects, places, people that communicate with each other through data and meaning exchange is a great opportunity for cities of the near future. The core innovation of liminal space concept is the reconfiguration of the city space that will transform urban computing and instigate new paradigm shift towards more free and more open technology.

The combination of these technologies work in between edges presented in the concept of scales that differentiate humans, buildings, malls, shops, cafes, restaurants and outside spaces, roads and sidewalks, cafe terraces, it works in the mode where agency flows freely between the actants, stimulating changes within all of them, stimulating users towards action, users stimulating change in the physical space. On the level of small neighborhood, it can be just outpouring of regular life onto the street, or by design for instance a front garden, that serves as a buffer between the private indoor space of the house and public space of the street.

The audio based and embedded interface, implementing the stimulative soundscape and interfacing with large-scale system, Foursquare, are the central parts of Navinko design that demonstrates fundamental principles of the liminal space. It connects people, bicycles, city and technology to re-think and re-design the way we interact with places we know or places we want to explore. Navinko overlays the city with soundscape, guiding, stimulating, nudging and luring people to locations they presumably have some interest in. With this hypothesis the design was released to public and subsequently extensively tested at two different occasions with public audience.

Chapter 4

Experiencing Liminal Space with Navinko Soundscape

Designing technology for liminal space means weaving it into the fabric of the city. It must seamlessly integrate both people and the urban space populated by other actants. At the same time, liminal space is a concept that cannot be tested outside of the urban space.

To evaluate the hypothesis of Navinko soundscape as an instantiation of liminal space, I conducted a user test that was carried out around Shibuya station. The test was carried out by an observation of user's behavior in order to discover and understand their user experience with the system. The environment was chosen specifically to provide street with little traffic and high density of shops, restaurants, bars, cafes and public spaces as well as institutions. The basic distribution of points of interest (POI), as shown in figure 4.5 on page 139, was chosen with relatively ideal distribution of the points in space. In addition to that, you can see the Foursquare points of interest imported through API into Navinko system. These POIs were then associated with professionally designed sounds and while played together produced musical composition. The sounds were mostly chimes, very short and designed to be pleasant to listen to even while layered and combined together within the application.

I selected a small area spanning from Shibuya station (see figure 4.1) towards park Yoyogi through Kamiyama-cho and part of Shinsen towns[58] as a test site. These is a good balance of density of establishments, such as

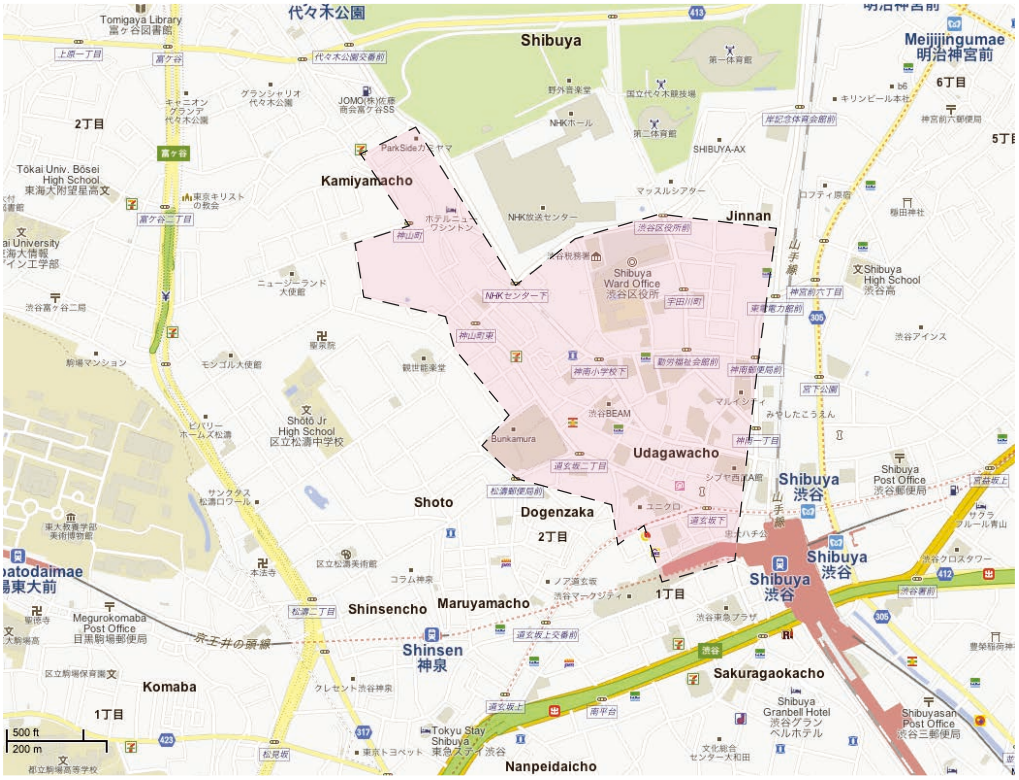

Figure 4.1: The approximate area designated for the test study. Google Maps.

shops, cafes, bookstores, and is generally area that is lively and also friendly towards bicycle traffic. There is a little automobile traffic and there are no major roads or other obstacles that would make free roaming of people on the bicycle.

The Kamiyama-cho area is very suitable as a site for general concept of liminal space. It features a mixture of actants, various types of places at different scales. It is therefore suitable as it allows for various interactions with space, buildings, and other entities that shape the experience. The involvement of large variety of actants at the same time prohibits the use of traditional methods and approaches to testing, such as closed and isolated lab environments, usual in traditional engineering and design research environments. In our case the city is both the site and the laboratory, and at the same time actively shapes the experience of users. The user test area was also selected with respect to this fact and was "prepared" in terms of optimizing it to provide the best user experience possible.

The test was conducted in March 2011 with a group of participants that had intermediate previous experience with city cycling. I intentionally selected people who use bicycle not only as a mean of transportation and commuting, but also as a source of entertainment. All of the users are to certain degree familiar with the area and cycled through it repeatedly in the past, however, not as a part of daily commute, rather while they were going from their own neighborhoods to Shibuya area for daily shopping, social activities or entertainment. The weather on the ay of the test was fair and thus the area was lively and the streets were busy with pedestrian traffic.

I structure this experiment around personal experience of users, because, rather than a scientific experiment, this evaluation aims at personal engagement of the users with the environment that the Navinko system enhances

Figure 4.2: Urban space of the test site. Google Maps.

and the effort is put towards finding out whether and how they feel their behavior is stimulated while using the system. In other words, the city and the environment strongly participate on the formation of the experience and cannot be excluded. Thus, the experiment was carried out in real conditions of real city, rather than in limited and controlled lab environment as traditional engineering approach would require.

This user test overall observes and interprets real experience with the system in real conditions, rather than within laboratory conditions. While this method is experimental in design research, it presents an interesting alternative to constructing complicated lab environments to test such complex projects that are aimed at the cities and that are difficult to test within the boundaries of traditional methods.

Figure 4.3: Another image from the urban space of the test site. Google Maps.

4.1 Method

To discover and understand the user experience of the cyclists with the embedded sound interface, generated soundscape and the Navinko system in general, I decided to use "cued-recall debrief" method, which puts emphasis on researching test subjects' affection and emotion. Bentley et al. (2005) emphasizes that this method specifically targets testing systems, where both affection and emotion are important for the success of these systems.

Traditional testing methods, such as recording users' interactions with the system, mapping their vision, interpreting video footage of how the users use the system are hardly applicable in Navinko.

The cued-recall method proposed by Bentley et al. (2005) for testing computer games and other entertainment systems has been similarly tested within media art, as Costello et al. (2005) notes. In both cases, the core of the research method is interpreting the data recorder by the observer with users' participation. In engineering, this is undesirable, as confrontation with the data might influence the users' interpretation of their own actions. While researching emotions and affection, however, this method proves to be useful in uncovering users' motivations, affectional perception and decision-making processes.

The cued-recall method in the case of sound interview had to be slightly changed. I conducted the preliminary interviews and the, instead of video recording the interaction, I recorded the position of users and GPS coordinates every five seconds to see where they are going. Also, the recordings of the audio output was recorded on a pass through recorder device connected between the users' iPhone and headphones. The users were then instructed to ride and experience the system. Upon finishing the rides which lasted

Figure 4.4: Starting place for the users' test rides. Google Maps.

for around 30 minutes, I conducted a longer interview of the users' experience while showing them the overlayed map of the POIs and their own movement. The results of this debriefing are presented here in edited and interpreted form.

4.1.1 Preliminary Interview

The preliminary interview was structured around how the users themselves perceive the test site, as well ad what are their relevant cycling habits when it comes to way-finding and orientation and how is their perception of urban space changes, while using bicycle as opposed to walking or taking the train (none of the users owns car nor motorcycle, these were thus ruled out from the comparison).

The preliminary interviews were short, around five to ten minutes, conducted in a relaxed manner without a fixed structure. All of the interviews were voice-recorded for later interpretation during the de-briefing sessions.

4.1.2 Introduction of Navinko to Users

After the preliminary interview, the users were explained the way Navinko system works and given the iPhone to create a user profile and log in. Users then set up Foursquare and chose their filters based on preferences, whether they want less places or more.

In addition to that, users were played all the sound types they were going to hear while using the application, as in previous user tests (see A.2 and A.3 on pages 190, resp. 193) we learned that the learning curve can be steep for some users. Consequently, they were played sample recordings of the soundscapes with different configurations and sound density.

After the demonstration and briefing finished, the users were presented with the area of the test site and were told to go around certain street and experience Navinko. There was no particular task, except the users were told that the soundscape they are presented with consists of the most famous places in the area in categories they were able to select while setting up the application.

4.1.3 Recording the Data and Users' Behavior

The data about users' movements during the test were periodically transmitted from the users' device into the server and recorded for the de-briefing use. For the best results, the device was mounted on the handlebars of the bicycle, securing the best GPS signal reception possible. The data the de-

Figure 4.5: The example locations which users where hearing during the test while cycling. Google Maps.

Rows 1 to 25 of 34

Select all. | Invert selection.

Id	name	latitude	longitude	category
1		35.657710	139.699190	0
2		35.657160	139.700650	1
3		35.655620	139.698410	2
4		35.659070	139.697730	3
5		35.668157	139.690060	0
6		35.667390	139.691190	1
7		35.666763	139.691230	2
8		35.666571	139.691860	3
9		35.666092	139.691700	4
10		35.665996	139.692510	0
11		35.665691	139.691830	1
12		35.665891	139.692550	2
13		35.665255	139.692550	3
14		35.664627	139.692500	4
15		35.664706	139.693580	0

Figure 4.6: The sample data with users' saved locations on the server used for testing. Google Maps.

vice recorded contained position and speed and were taken in five second interval which, while we take into an account average speed 15km/h, which means around four to five meters distances. The data were returned with the actual speed as well, therefore we were able during the de-brief where user slowed down and where sped up.

The recorded data about positions were then matched with the recording based on the real time stamp and therefore we could interpret with users what they heard and whether the sounds somehow influenced their behavior and de-briefed them together with using Google Maps street view to re-create the exact situation.

Figure 4.7: Bone conductive headphones that were used by users to address safety issues and prevent the Navinko application from blocking users hearing of their surrounding. Photo by author.

4.1.4 Debriefing Users after the Test

The debriefing sessions took place in a cafe in Shibuya right after the test, after a short period preparation, which consisted in retrieving the sound recording from the device the users were given and at the same time plotting their movement on the map.

After the preparatory phase, I conducted relaxed and unstructured interviews, as I aimed for uncovering users' emotions and affection while using the system, rather than seeking replies to some rigid survey type quantitative approach. We have went together with users through the logged data and looked at interesting locations through Google Maps™ to recall the exact setting and stimulate the memory of the user.

The de-briefing sessions took usually around 45min and users were initially queried about their general experience, how did they feel while using the system, what was their experience with the city and how connected they felt to the environment. After this general introductory discussion, we moved on to the reviewing users movement as mentioned above where they tried to recall the experience and feelings around the highlights that they themselves mentioned and emphasized as being key to forming their experience. Finally, we concluded with a loose discussion and reflection of Navinko system.

4.2 Users

I have selected three users to participate in the user test. They all had intermediate experience with city cycling, but they are not regular everyday commuters. They all have positive feelings about cycling and do so for multiple reasons including convenience and entertainment.

Two of the users are male in around 30 years of age. They are both cycling multiple times a week within the area of Shibuya. One of them lives in Sasazuka (User A) and passes directly through the Kamiyama-cho area while cycling between home Shibuya area. The second one (User B) lives near Shimo-Kitazawa and thus he also passes the test site regularly, yet only for a short period of the commute. Only one of them uses iPhone (while the other uses regular Japanese feature keitai), but they are both keen technology users.

The third user (User C) is a woman, 29 years old, who lives at the edge of Kamiyama-cho and works in Shibuya area as an employee of large media company. Yet she rarely commutes to work on a bicycle for various reasons. However, she mainly uses bicycle for grocery shopping, going out with friends and going to the gym. She has an iPhone and uses it actively, as well as technology in general.

The users were selected to reflect one of the premises of the Navinko project: it is not a tool for navigation or daily commuters, but mainly an artifact addressing entertainment and unusual innovative experiences with urban space. Therefore, the user group that represents the type of users that would present an early adopter group of such project.

There was also an emphasis on finding a people that will presumable find enjoyment in exploration of the city, which means people that have some relation to the site, as well as are outgoing and social, and thus would be interested in the city exploration per se.

In preliminary interviews I tried to gather information about users' previous experience with cycling and with their cycling habits in the city. I was especially focusing on what is purpose of their cycling and what is their experience with the area and what habits they have.

All of them expressed passion for cycling, seeing it not only as a simple mean of transportation, but also as an entertainment, which ranges across various features of bicycling in the city. User A notes: "I love the speed you can god and how quickly you can move around the city, I am sometimes the faster than cars, because they are caught up in the congestion." The agility of the bicycle is indeed one of the key advantages, together with
While asked about the routes they take, all of them expressed that they take similar, but not always the same routes. The criteria they influence their decisions were revolving around personal mood and externalities, such as weather, time of the day, whether the streets are crowded or not, whether it is light or dark, whether they are in the hurry or not.

Only the user C uses actively Foursquare, but other users knew the principle of the service as well, even though they did not have any active accounts. They were therefore using a set of POIs that were selected based on popularity and the number of check-ins and the categories that users selected as being interested in. They were all very positive about the test when briefed and were looking forward and keen on trying the new technology in the test.

4.3 Results

All of the users rode around 3.5km to 4km within the test site area as can be seen at figure 4.9. Even though the users were not told where to go, they roamed around in different directions. The rides usually took around 20min with start and end point near Bunkamura shopping mall. None of the users reported any technical issues, as well as none of them strayed away completely from the testing area.

In the de-briefing session and the interpretation of the results, I consid-

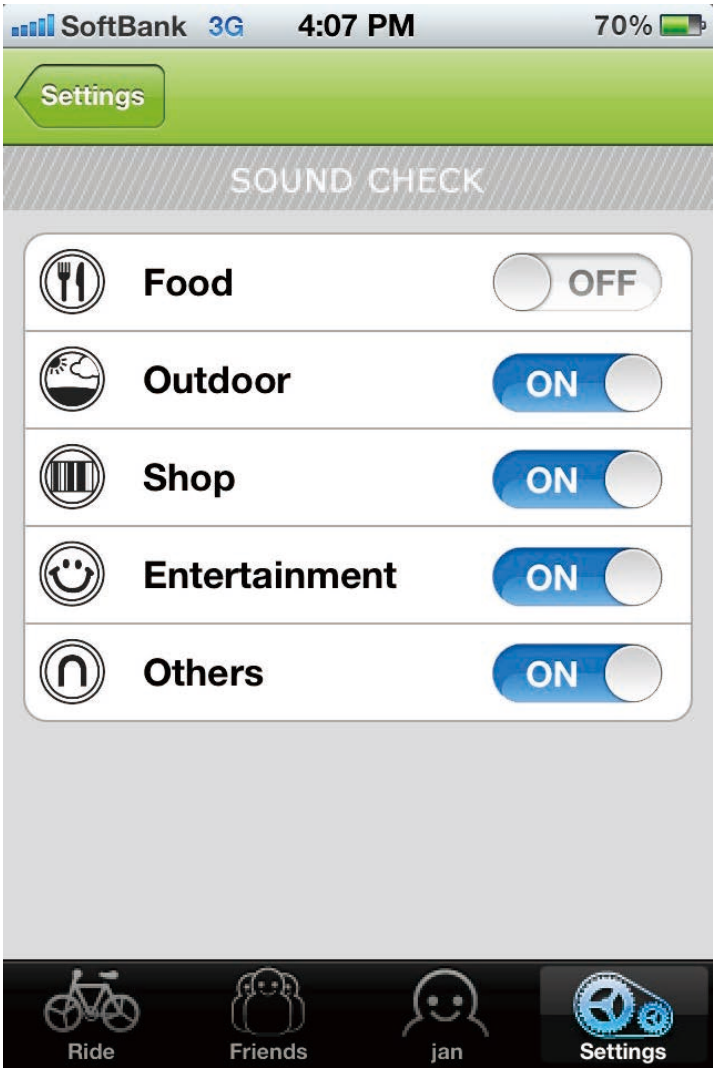

Figure 4.8: Foursquare connected to Navinko with different sound types. Users in the test were able to select which ones to enable and listen to them repeatedly as a process of learning.

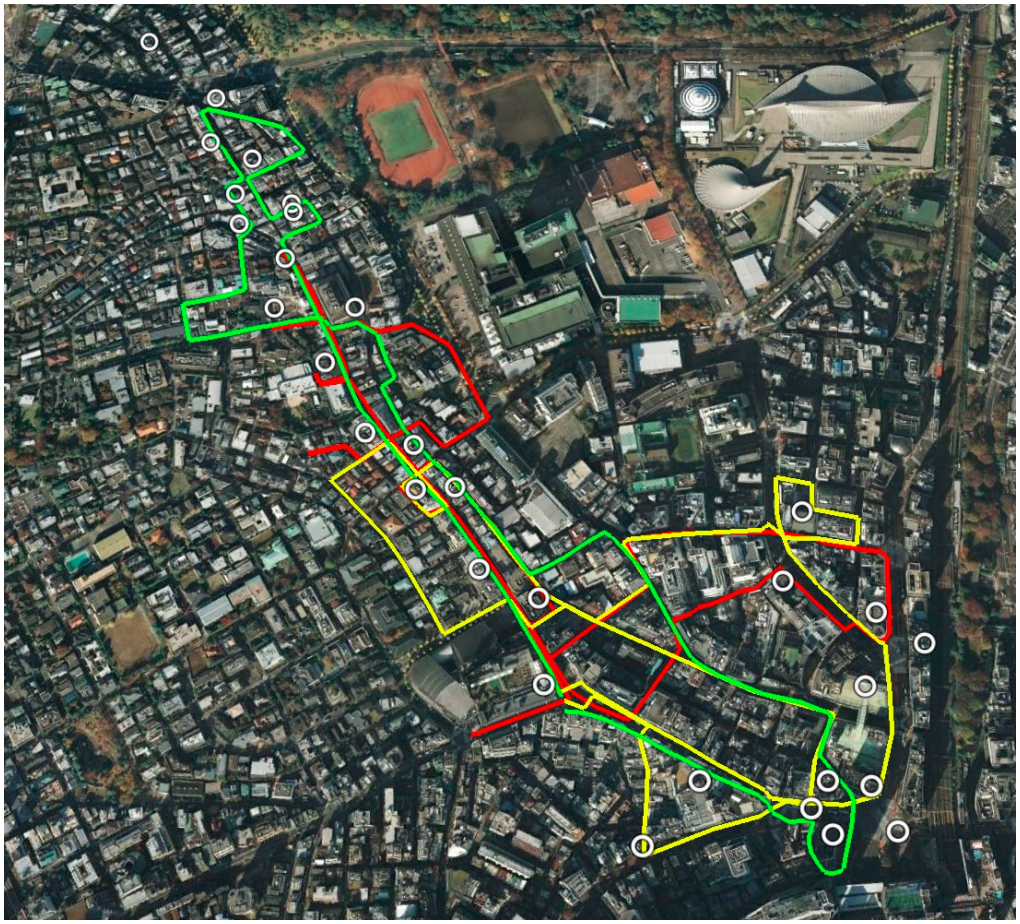

Figure 4.9: Combined overview of users' path: User A - Red, User B - Green, User C - Yellow. Data graphed by Google Maps™.

ered not only the ride data collected by device, but more the users' own comments on the ride data when they were presented back to them after being mapped by Lat./Long. coordinates into KML file in Google Earth identical to the figure 4.9. We discussed what were their feelings and how was the experience in certain areas and whether they were able to discover things and finally, how the soundscape influenced their decision-making.

4.3.1 Study of User A

User A rides bicycle quite often, mostly as matter of getting from point A to B. He had a very good knowledge of the test area, as it was the place where he spends big portion of his free time to meet people, socialize, shop and visit cultural events. Despite that, he was curious to explore the area with a different mindset of being guided to places that others thought were interesting.

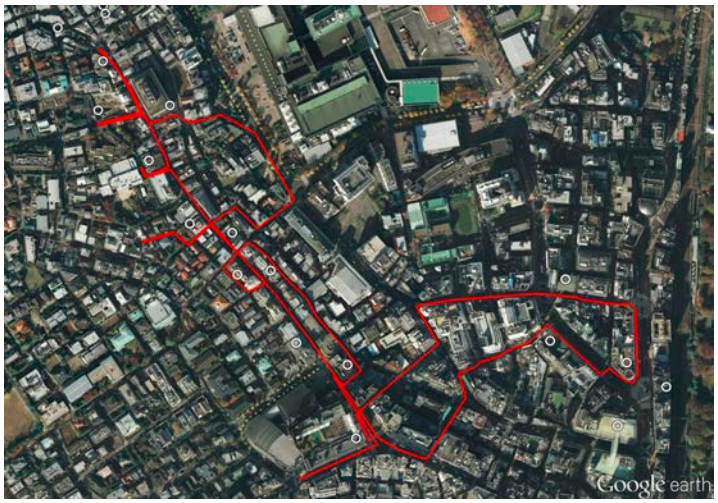

Figure 4.10: The ride data of user A. Total ride length is 3.55km.

User A rode the longest distance of 3.55km and his ride stretched over a majority of the testing area. Contrary to the other two users, user A rode first towards Hachiko, rather than towards Kamiyama-cho. He got to

Kamiyama-cho later and explored it for some time. I focused on this in the de-briefing.

First we discussed the beginning of the ride, when he first went from Bunka-mura towards Shibuya crossing and recalls the experience there: "While I rode towards Shibuya, I heard a lot of sounds around Hachiko area, it was interesting, but I could not figure out what the sounds mean". When asked about why did he not explore or stayed for a longer time, he replied pragmatically "The area itself is too crowded to ride on the sidewalk and there is a lot of traffic, I did not feel like I wander around too much".

Consequently, he found his way to the back of the test area close to Yamanote line tracks. When asked, what made him to go there, he recalls: "I like that area because it is a little bit calmer than the area around Hachiko. As I started going there, I also heard that the sounds that died of as I left Hachiko started re-appearing. I thought I am on the right track."

When we discussed the final part of the ride, he slowed down a little bit and started going around: "I am not so much familiar with this area, as I usually go to Shibuya and just pass through Kamiyama-cho." When I asked about the experience with the soundscape, he noted that "it started to be really interesting, because I could cycle more freely, these street are good for cycling."

Finally, we discussed whether, if and how Navinko changed his perceptions of space while riding: "I liked the sounds and enjoyed that I can influence the way the soundscape sounds a lot. I was not able to find the places, or I did not know if the place I am is actually the place on the map, but it did not matter to me too much. I enjoyed the riding itself." On the topic of decision-making, in terms of deciding where to go, he noted: "I knew somehow I am supposed to follow the sounds, but the point was that they

sounded nice and I wanted to hear them more, so when the sounds started to fade, I tried to return to the area were there was more."

4.3.2 Study of User B

User B rides through the test area the least of all subjects, as he lives in the Shimo-Kitazawa area and on regular commutes to Shibuya, he enters the area near Bunkamura and continues to Shibuya. In the preliminary interview, he expressed interest in exploring the area towards Kamiyacho: "It is an interesting area, but I hardly ever go there, it will be a good chance to explore it."

Figure 4.11: The ride data of user A. Total ride length is 3.21km.

Once he started riding, he went all the way back of Kamiyama-cho area. "First I was just enjoying the soundscape as it was gradually changing." Later on, in the back of Kamiyama-cho, he knew that the test area ends somewhere before Inokashira street. He then went on and rode for some time around that area. His riding became slower and he was going around the blocks a lot. "I wanted to find out the exact places where the sounds come from, but I could not make it out what the exact place is. Only one place I figured out right, the bookshop, when I went a bit too far and there

was only one sound I heard, on they way I passed it and I said to myself, this must be it." In addition to the effort he made finding places on the bicycle, this user adds: "I actually had urge to get off the bicycle and try to find the place by looking at the display."

According to the de-briefing session, user B enjoyed riding with Navinko, even though he was skeptical about finding places: "I enjoyed the sounds a lot, it was like riding in the movie, the sound changes with the scene and is synchronized, but I do not think that it is very useful for finding places. Maybe if I were on foot, I could probably look for the places itself better. On the bike, I only wanted to ride." This is not the first time users expressed skepticism about the bicycle. This one is similar to one of the preliminary tests (see section A.1.6), where test subject expressed similar opinion.

In the end, this user also went to Hachiko. When I de-briefed him and asked why did he go while he was stating before that he has more interest in the Kamiyama-cho area, he recalled: "The Kamiyama-cho area was fun, but I thought Hachiko might be better, as I supposed there is higher density of the sounds and I wanted to hear it." This was, in fact a misconception based on the general image of Shibuya crossing as a place with image of having high density and saturation. While I asked user B about he experience, he replied: "I was a little bit disappointed, the sounds were very similar to those in Kamiyama-cho, but there was much more people." But after all, he notes that: "the area around Hachiko was after all interesting, I felt somewhat connected to the space and to the situation. When I rode around and the sounds were changing as I was moving, it was a really great feeling, like I am creating my own soundtrack for myself."

4.3.3 Study of User C

The user C lives in Kamiyama-cho area. She could use a bicycle for her work commute, but does not do it too often, as she works in media company and cycling does not meet with her company's culture and dress style. She uses the bicycle, however, quite often in her free time, similarly to other test subjects to go shopping and socializing in the area.

She rode the least, 3.03km, but her ride stretched over the whole are of the test site. When I asked her, what was her experience, she recalled: "It was very interesting feeling. It was like I felt some connection with the space, the space reacted to my movement and I felt like I am reacting more to the space." Further on, she noted, that she "never really thought of where I am going, but I remembered the boundaries of the test site and once I almost lost all the sounds, near the Yamanote tracks, so I went back towards the hill where NHK is." With respect to that she made an interesting observation: "It seemed to me after a while that the density of the soundscape somehow relates to the density of the people and shops". Then I told it might be because the Foursquare check-ins actually are in the places with higher density, she opposed: "Would it not be better then, if the soundscape would lead me more towards the places that are different? I had one feeling like that close to the end of the ride in Kamiyama-cho, where I heard a sound from the side and I turned there to look for something."
When I asked her about the actual place, whether she was able to find it, she replied: "I did not care so much about the actual place, to me the interesting point was that it felt somehow mysterious, like nothing I experienced before while riding in the city. Maybe if it was really quite like in the forest and I heard music coming from somewhere. But then I might be scared and this time I obviously was not."

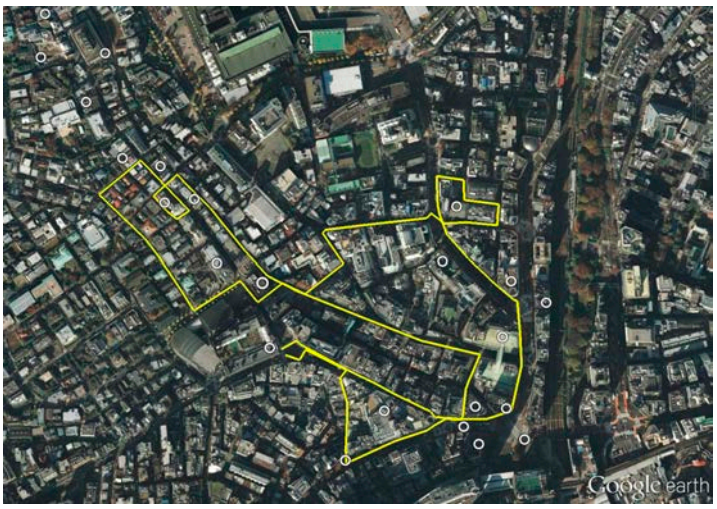

Figure 4.12: The ride data of user A. Total ride length is 3.03km.

4.4 Reflection

The users expressed the impression they were stimulated by the sounds towards behavior change. At the same time, because it was presented in the form of generated soundscape that resembled music, the users did not feel intimidated by the interface and did not feel forced because they could simply ignore the fact that the system tries to move them around and could freely move around.

The user interviews strongly showed the connection that forms between people who used Navinko and the space they were in. Their perception of space changed based on the clues they were getting and they felt motivated to move around, to have interaction with the soundscape and the urban space itself.

In more detail, the user study also revealed several important aspects related to the modes of interaction: especially those related to finding places. We could conclude, that the system supported both of these modes of interaction.

Users either indeed associated sounds with places and actively explored these, trying to locate them and find out which is the place someone else shared and why they did that. This "place-finding" mode, however, is at present suffering from technical difficulties given by limitations in GPS accuracy and also limitations of the sound interface. Contrary to the difficulties, users were in many cases successful with finding an exact place. The most difficulty proven to be locating the actual place when users were in its very near vicinity.

When the user was unable to locate the place, their perception usually "switched" to the other mode, where the user focuses "away" from the way-finding and locating places and focuses on his or her *personal engagement and connection with space* created by the loop of movement-soundscape relationship where the user exchanges data with space which in reverse stimulates the user to act. In both cases the users are entangled in active exchange with the space that is facilitated by Navinko application and administered through the sound interface. This agency of the environment is made by the technology, that collects the data about locations and transforms them in to sound.

The users expressed the connection with space, feeling of exchange and stimulation that they generate the soundscape with their movement and the way that soundscape changes is influencing their movement. That is the stimulation. The exchange and mutual influence is a propriety of the liminal space - the users were experiencing the *liminal space*.

The identification of the places themselves was, however, less successful. Even though users were able to identify the area, they were not exactly sure about the place itself. As one user noted, when she wanted to find an actual place and make sure, she wanted to get off the bicycle, look at the screen and try to figure out what the place is and where exactly it is. This

functionality, was however not intention of the Navinko application.

Enjoying the music as an experience and associating the sounds with actual locations and then following the sounds to explore and discover present an interesting departure point for future discussion and research. In the first case, the discovery is stimulated by just varying soundscape (user moved around randomly, the sound changed) while the second one if deeper understanding (there is a sound that goes with place and the user was able to identify the sound and discover the place). The question that arises is whether both of the modes are experiences with liminal space, or if it is only one of them (and which). I argue, that the discovery of the single place *does not matter* to the liminal space concept.

The most important component to the concept of Navinko as design artifact that demonstrates the liminal space in the form of, as I argue, the agency that flows between the people and the environment and the role technology plays in achieving and enabling this flow. This interplay where technology transforms data about the space and then turns the data into stimuli that users then follow. This concept, proposed as a new configuration for people, technology and the city, worked within Navinko as an influencing force in driving people's decisions about movement. Movement itself, while it is the target of Navinko, is not the target of the liminal space itself, it is one example of the liminal space in effect in the city.

What I also learned for the Navinko project could be expanded by adding more hints to the user, for example by combining with vibration based cues about the distance from places to increase the ability of users to find and locate places with increased precision and accuracy. In other words, the technology can combine audio interface with other embedded, persuasive technologies that reside close to the senses of the user and support more passive, symbiotic interaction with the technology. Consequently, another

logical step would be to extend the experience of people with the space in the direction of designing some interactions with the actual places, such as reward systems, badges or other game elements discussed earlier.

Chapter 5

Conclusion - Liminal Space: A New Vision for the Urban Computing

In this dissertation, I tried to point out an innovative concept of the urban space, where the elements constituting experience, city, technology and people, become organized in a different, innovative manner as a "liminal space". I propose "liminal space" as a vision of a convergence of the two main contemporary technology trends associated with urban computing design research: so-called companion and situated technologies. I argue we need this vision as a response to design discussions that often only summarize and demonstrate the technological possibilities, while leaving open the issues of social change and transformation of urban space and everyday life. To realize this vision, the companion technologies, represented by smartphones and portable devices, need to be designed to support multiple modalities of continual interaction, transcending the current, screen-based paradigm of the design of these devices. Situated technologies, embedded in the space, need to not only collect, but also respond to the increasing amounts of heterogenous data related to concrete contexts and situations in urban environments. I argue that the convergence of these two main trends will support a symbiotic relation between people, technology and spaces where the data are exchanged to create new collectives through continual multi-modal interfaces.

Liminal space is the vision that rethinks the way we design for contem-

porary urban space to stimulate social change. It combines technologies situated in urban space with devices that we carry around with us, that I call companion technologies. Situated technologies can be tailor made to the site or location that we choose, respecting its specifics, reacting to its changes, evolve and adjust together. This tight link produces contextual and situational awareness, represented in the data about the location or space. On the other hand, companion technologies reside very close to our bodies. We are intimate with these devices, letting them reside close to our bodies, entrusting them with managing our lives, offloading our cognition and agency to them. We dictate to them our agenda, let them to take care of our everyday tasks, such as waking up, entrusting them with the ability to act.

The interplay of the location and situation specific data with intimate companion interfaces motivates people to social action or behavior change. The strategy to achieve the vision of liminal space aims to re-think the relation of city, technologies and people. Within liminal space, technology, people and all other entities that constitute urban experience, are perceived as equal, symmetric actants that all have an ability to act. Under such circumstances, technology can get exclusive access to embedded, always-on interfaces that tap to human senses and act upon them, nudge to perform small, immediate actions and decisions. The sum of all these actions, while in large volume, can ultimately alter physical appearance and physical design of the urban space, reconfigure it and make it more livable, enjoyable and sustainable.

Technologies, both companion and situated, are weaved in to the fabric of the city, our bodies and translate the urban scale into human and vice-versa. Within liminal space, a block of houses and one user are treated as equal elements of information exchange in a different configuration. It is a configuration of space that remembers, reacts, adjusts and reforms with

help of circulating data that stimulate interactions.

New configurations of technology, people and the city focus on innovative results where we expect technologies to help us understand and manage the different limits of our biological, social and political existence rather than to support the narrow techno-optimist forms of enhancement and extension. This set of research questions was tested by design of Navinko application that interconnects global Foursquare service with local specifics of shared databases of locations that are smelted into musical experience that stimulates users to explore and discover their surroundings through constant use of headphones. The sensation of liminal space they experience makes them go around and enjoy the interplay between movement, city space facilitated by what they actually hear.

The general approach to the urban computing design for this "post-interactive" era simply prefers embedded interfaces that support engagement through monitoring, visualizing, reminding and persuading as the main functions of the new tools and applications working with large numbers of human and non-human actants and their collectives (institutions, stakeholders, environment). The notion of "liminal spaces" helps us to create a new types of local and global awareness and support various assemblages - entities and communities in the contexts of all scales - our neighborhoods, cities, countries or even larger assemblages and the biological habitat.

The dramatical increase of data available about the way users interact with other actants, rather than only between each other, coupled with the personal, intimate interfaces presents an opportunity for a next step in the evolution of the city and its design, an evolution that presumes radical changes in the way we perceive space and the interplay between all the entities that occupy it. Such cities will be more livable and enjoyable and people will be able to participate on the formation of the urban space more.

The "Big data"[59] of today, petabytes of information about the way we socialize, interact, shop, consume, entertain ourselves that are being now aggregated within the internet will grow many times larger as they start coming from the physical space. The neuron layer of the cities represented by situated technologies needs to connect to the senses of the people that inhabit it. Through this vision of liminal space we can, as I argue, achieve goals of new types of cities, envisioned across disciplines, such as architecture, technology and engineering and also social sciences.

The application Navinko partially implements elementary specifics of these new configurations by interfacing with larger information system and delivering information from it via embedded audio interface. Navinko functionality also implements the concept of nudging via associating locations with sounds and generating soundscape that overlays usual sounds of the city. It was proven that the stimulative embedded interface stimulates users to divert from their paths to explore and discover their environment, when certain conditions are met. These conditions ranged from emotional and personal to rational ones[60]. Navinko project presents first step, for further research, I propose to further structure the interaction design not only around sounds, but also around using other sensual inputs, such as touch and vibration semiotically coded to certain locations of the body. Such more complex approach will also allow to focus on stimulation towards more structured action, that would go beyond simple space exploration. Navinko prototype emphasizes passive interaction in the digital sphere and focuses on the stimulating the translation of the meaning into the action in the digital.

The trajectories for theoretical research can be multiple. There is a need to explore further the reaction of users towards the companion technology and intimacy, how well are users prepare for adopting companion technology on

more and more intimate levels and offloading more decisions to it. Another possible research that needs to be explored is the effectivity of nudges and offloaded agency in the real environment as well as test the effectivity of persuasive powers on the companion technologies. The research effort in situated technologies should focus on how to easily and cheaply build embedded applications tailor made to specific sites and specific contexts of various locations, such as neighborhoods, city blocks, buildings and various other collectives aligned by having different things in common. It is also important that these applications create open data, that can be not only delivered to users via companion devices, but also used within other applications to generate new types data combinations and support creating new types of interactions. The cultural trajectory also plays a role. Where technology of companion, especially in smartphone market, is to a great degree globalized, the situated technologies, often designed in custom places and custom ways, can be an alternative that will promote locally as well as culturally specific applications, respecting the cultural specifics of the contemporary cities on different continents.

We may be touching probably the most interesting shift in the concept of the user: in the complexity of the present mega-cities, it may be time to rethink the notion of the "user" itself. Are humans really the only "users"? And should be humans the only only ones privileged to be users? The higher and more complex goals represented by the agency of various complex assemblages could also stimulate us to re-think the argument: would it not be beneficial to start thinking about, let us say, a neighborhood as user that wants to excel in living conditions and thus strives to stimulate all of its inhabitants towards certain behavior? Or would it not be beneficial to rethink city itself as the big organism that gravitates to what we, humans, call "healthy living"? This alternative seems to be really interesting, as these larger goals are associated with further advancing the humanity and the quality of living, sustainability and ecological aspects of cities as mega-

organisms.

Such future presupposes users - citizens who are educated and informed, and in whose life the technology is integrated to greater extent than at present and who respect augmentation and symbiosis with these larger entities everyone is part of beyond the individual level, or at best beyond the level of building or a street. The cities should be designed to have agency to stimulate users towards solving the problems of these cities - pollution, traffic jams, health condition of its inhabitants, raising aesthetic qualities, living environments. The ultimate proposal of this dissertation aims towards creating a new type of space where users are not afraid of interacting with the space, feel engaged while given hints and stimuli. A space where people will feel engaged and through this enjoyment contribute to the social change.

Notes

[1]It is unquestionable the technology in contemporary cities plays an increasingly important role. With the present advances in technology and upcoming challenges, everyone from policymakers to designers is looking the possibilities we have to address the necessary change and support it with innovative solutions at the same time.

[2]Such as the scale of body, immediate personal space that surrounds it,

[3]One of such is the first location specific music album called The National Mall released by Bluebrain in spring 2011, that resembles what Navinko project addressed earlier, but focusing more on the actual music. For details see http://www.bluebra.in/.

[4]PDAs, Personal Digital Assistants, for example, did not really took off, even though they provided very similar functionality as today's smartphones, however, it was the fact they were not connected to the internet, together with technical limitations, that did not make the too popular.

[5]There is an ongoing debate on the terms, mainly between "urban computing" and "urban informatics". In the latest publication Foth and Choi (2011) propose the term "urban informatics" for city as nexus of places, people and technology. In the latest work, he coins this definition: "Urban Informatics [capitalization by author] is the study, design and practice of urban experiences across different urban contexts that are created by new opportunities of real-time, ubiquitous technology and the augmentation that mediates the physical and digital layers of people networks and urban infrastructures." We can certainly find some nuances while we start carefully immersing ourselves into comparing definitions: "informatics - the collection, classification, storage, retrieval, and dissemination of recorded knowledge ... as ... science", according to Websters online dictionary - and "computing - any goal-oriented activity requiring, benefiting from, or creating computers [thus] includes designing and building hardware and software systems for a wide range of purposes; processing, structuring, and managing various kinds of information" (Shackelford et al., 2006). When we look closely on what research is being classified as "urban computing" and "urban informatics" we find little differences. Or, as Foth puts it, "computing" does not emphasize and adequately represents triad of people, place and technology. Foth claims that computing falls short especially at encompassing the "people" element. "Informatics" references information systems and, according to Foth and Choi (2011), points towards softer aspects of "information exchange, communication and interaction, social networks, and human knowledge". As the terms say unsettled, I will use urban computing in this thesis.

[6]Good example are social media and so-called Web 2.0 - more and more people produce digital content through services like Facebook, Twitter, Flickr. Twitter drives

whole revolutions. The use of media increasingly in the production mode has, however, little impact on the actual space we live in. The closest we can get with our approach is most likely public screens, that are sometimes used to project football matches but more often to project advertising (that often has aesthetic qualities). The importance of the keitai / smartphone is extremely high. It is increasingly becoming not only a tool to get in touch with others - friends, families, but there is also a great potential to become an interface to the city and to different types and modes of interaction. This potential becomes slowly unfolding in last few years when we see the popularization of smartphone applications and the extent they change the way we use the city. There are applications for train schedules, jogging routes, dining and even finding a cheap beer. In the early times of last decade when the GPS entered consumer-level market, this seemed like a dream that then-avant-garde cohort of locative media artists tried to envision what these applications might be like.

[7]With advances in CAD and other design processes. The implementation of information systems in cars also transformed them from a four-wheeled, mechanical machines controlled by pedals connected to engine and brakes via hydraulics or pull-strings into computers with four wheels and pedals attached to control computed actions of fuel injection or break pads pressure on the discs. Yet, our perception of the archetype of a "car" did not change that much.

[8]The technical innovation is very often depicted in in the cinema or literature. One of the examples of the technical innovation can be a digital signage - when we were first widely confronted with the idea of personalized advertising based on retina scanners in the movie Minority Report, we certainly perceived it as something well out of our reach. In 2010, NEC announces the working prototype1 of CV-based system that detects peoples gender and age. While it is still not the same as narrowing down the target group to one or few advertisements as we could see, it is not so far. And to certain extent, it is an innovation of contemporary recommendations engines. The advertising scene in Minority Report serves a purpose, but we could also think about other possible applications that would be probably more fun that just ads and would make better services. Such as matchmaking (I am available here and now), where a service that announces the physical proximity of a potential match to both participants helping them to overcome the initial hesitation and shyness through semi-public announcement they both hear and see at the same time. A little played down version then could work as very advanced friend finder, or more precisely friend maker.

[9]There is an ongoing discussion about post-silicone computing, as the material has physical limits it can be pushed to and chip manufacturers are hitting the limits with current designs. It is a fact, that development in microchip industry, represented mostly

by Intel, is finding another ways to push further innovation. Good example are multi-core computers, as the clocking speed of a single core cannot be pushed much further beyond 4 Ghz.

[10]The Moore's Law, that serves as a paramount in the processing power predictions is slowly changing. Why the timeframe within the processing speed doubled used to be around 18 months, at present it is around 24 months and it is discussed that in around 5 years it will be 36 months. This fact will influence design of technology, prolonging the expected lifetime of devices using microchips.

[11]Uber is a service that allows users to call a taxi based from Uber application on their Android or iOS device. They can then plan the route and track the car via GPS. More information at http://www.uber.com.

[12]EggDrop is a local, GPS enabled marketplace, where you can see all the sales and deals that are relevant to your location within given perimeter. More info at http://www.eggdrop.com.

[13]The Jawbone UP is an iPhone accessory, a bracelet that logs accelerometer data both during the day, interpreting our movement patterns, and night, observing the way we sleep. It then claims to be able to stimulate its users to eat healthier and wake them at the right times. However, it have been troubled by the poor user experience, especially with the mobile app that is supposed to support it. See more at http://jawbone.com/up and http://www.fastcodesign.com/1665491/the-jawbone-up-fails-but-teaches-3-golden-rules-for-experience-design on its critique Cliff Kuang.

[14]As most keen users of GitHub can certainly confirm.

[15]We have to keep in mind, that Latour warns against adopting heavy network oriented terminology for the resemblances with computer and other networks that is confusing, as the nature of relations described by ANT is different (Latour, 2005).

[16]Dualist theories put human as something special and strongly advocate differences for human and non-human.

[17]While we have to keep in mind very few basic conditions, such as supplying the alarm clock with electricity or wind it, if its just mechanical.

[18]ANT calls these complex objects that are composed of many other, smaller actants - technological, social and human - *quasi-objects* or *tokens*. The effect of hiding the smaller participating actants from the view of the user (pilot, in the case of the plane or a driver, in the case of the car) is called *punctualisation*. These terms are part of ANT theory, but go beyond the necessary theoretical scope of my argument.

[19]The breakdown itself is decreasing the *punctualisation*, as one of the actants in the network fails to pass the *token*

[20]The complex systems that involve both advanced technological

[21]When *punctualisation* decreases and *quasi-object* stops being passes around within the actor networks.

[22]It is an interesting moment when the decrease of *punctualisation* in one system means the increase in the other.

[23]The term "liminal space" is freely built on association with liminality, that "refers to in-between situations and conditions that are characterized by the dislocation of established structures, the reversal of hierarchies, and uncertainty regarding the continuity of tradition and future outcomes." (Horvath et al., 2009).

[24]According to Rekimoto Rekimoto (2011), we are approaching the time when human and computer will be integrated and when computers will have much higher impact on our behavior. Rekimoto's lab is experimenting with smile detection to determine human happiness in an effort to improve it, while, for example a user wants to open a refrigerator to get food. These are the examples of nudges that can be designed in to our environment.

[25]The rewards will be an extension of the present applications, such as FourSquare, that awards users with digital badges. This movement is presently being discussed as "gamification" of technologies and into various applications. In fact, the gamification phenomena is gaining traction and permeate other technologies.

[26]In this case we mean user-centered or human-centered.

[27]Such as municipal policies, or policymakers.

[28]Here I argue we need to step further than Augmented Reality does, as it is ultimately cluttering to the experience of the urban landscape. The obstruction of the vision, overlaying digital information over the real one is exciting concept, but current market implementation - walking around and looking at the world through the display of the mobile device - is far from the seamless experience.

[29]Applying ANT into urban computing design is strongly connected to the question of faith in technology and techno optimism. To be able to open the connection between us and the space around us, I argue that we have to adopt a rather pioneering and brave stance. Being able to give away control is traditionally a problem that is tightly following most of the inventions and technological advance of mankind, information technologies included. We are lucky, though, that failures in our field most of the time create just a disappointed face.There is a great amount of literature on the fear of technology and skepticism, or refusal of the new inventions, mostly for the fear of unknown.

[30]Such as using social media, reading news, books, etc..

[31]I am focusing on the urban space, but this notion of space is general

[32]The main critique that is usually raised against the concept of Actant in the ANT is, in fact, the lack a single, widely accepted definition. However, the concept of actant

as presented here *does not* rigorously follows an ANT actant, with having avoiding interpretivism on mind (Cordella, 2003). Very often, the definition of actant gets reduced to any entity that has agency, or variation of this, which leaves us in the dark.

[33]In traditional Systems theory (cf. Talcott Parsons or Niklas Luhmann), the reality is described as being composed of "actors" that "act" and "systems" that "behave". The ANT is interesting especially in the fact, that a larger entity, such as an institution (Japan Post), can be itself an actant in another Actor-network. This makes ANT very versatile in describing reality without using the distinctions of actors, systems, et cetera.

[34]The 'meaning of data' here means that while certain number can may not have any meaning to a certain user, but the technology has a power to translate the data. Such meaning problems have been documented for example with measurements of data after Fukushima disaster, when Japanese citizens were unable to understand the meaning of units and amounts of radiation and potential immediate and long-term effects on their health and surroundings. That is, indeed, an extreme situation. However, similarly problematic can prove to be understanding safety levels of CO2. When we take walking around the city as an example, the technology can try to steer us to take the way where pollution is lower.

[35]McCullough talks about protocols as being important. Protocols are already existing, the interaction paradigms for the spaces they should work in are missing. To name a few, Bluetooth never really broke through except one-to-one device-accessory connections, but XBee standard is, at least in design research widely accepted standard. The widespread RFID that powers all sorts of access cards is slowly evolving to more elaborate NFC standard. On a higher level, mobile internet underlies and connects these systems and allows for data exchange between further locations. There is, though, a greater challenge, to build successful, small-scale projects that would be later scaled up.

[36]This interpretation can happen through Bayesian networks or any other probability defining technologies, as used in many present social services, mostly in terms of recommendation engines.

[37]Digital signage PA system is trains is somewhat partially falling into category of situated technologies, for being embedded in space and partially context-aware (showing the information related to the status of the train lines as well as information about approaching stations).

[38]Such as with traditional social media expanding into mobile space.

[39]Yaneva (2011) excitingly observes and explains the process from the idea to through the realization, to the use of the building, showing the interactions of all stakeholders that influence such a complex process, as construction of a building is. While urban computing applications may be smaller in terms of matter, they may often be even

more complex in terms of complexity of actor networks.

[40]In Tokyo the cycling on the pavement is very widespread phenomena, however it is officially forbidden.

[41]The city organization and urban planning influence the nature of these sites. Tokyo, for example, is organized around public transport, which means there is a concentration of shops, restaurants, and other services usually in the immediate vicinity of the station, usually one street that serves also as a place for socializing. In western cities with different density, this role is often taken up by shopping malls, that also have restaurants, cinemas, gyms and are usually designed to be easily reachable by cars.

[42]These "mashups" gained popularity during Web 2.0 era as an alternative to traditional "portal" data model. Mashup, taking advantage of using APIs, were able to bring new functionality and service at higher pace than the traditional Web 1.0 applications and services, that had to first aggregate all the data, often over the course of months or even years.

[43]I talk about "produce", rather than the "product". The reason is that data in liminal are of somewhat "organic" origin. They are product of interaction of people, technology and environment.

[44]Some might argue that the globalization has already rendered local contexts futile. I think that the bottom-up approach is powerful enough to reintroduce these contexts and, at least to certain limited extent, reverse the processes that uniform users around the world. Steve Jobs from Apple have supposedly said "for young people, this whole world is the same now" (Isaacson, 2011).

[45]The interplay between the situated and companion technologies demands for holistic thinking of the design, rather than just concentrating on the benefits of single user, as Norman (2005) mentions. The technology centered around agency and placed in liminal spaces, can react better towards flows (Sheller, 2006) constantly changing situation of actants movement around the city and perpetuating reconfiguration of contexts. Facilitating higher flows of agency between the actants can be achieved when the design focuses on the interconnecting the actants. Such technology can connect vertically the different scales of places and users themselves. Such technologies, while successfully working in one building, or one city block, can later be scaled up.

[46]I am using the word "keitai" to express certain differences in the interaction schemes that we can observe among the Japanese and the way they interact with the technology. There are also differences in used technologies - such as wide penetration of NFC - among the devices available on the Japanese market. These differences, however, are being razed to the ground with the advent of smartphones (Miyata and Boase, 2008; Nguyen, 2004).

[47]This is represented by the pleiad of devices tied into Apple's iOS, Google's Android and Microsoft's Windows Mobile platforms and services.

[48]The applications available for iOS ecosystem target a great number of activities, hobbies, business utilities, etc.

[49]Smartphones integrate telephone, cameras, fax, alarm clocks, calendars, and many other functions that were earlier facilitated by separate devices.

[50]It is being attributed to Apple to revolutionize music, tablet, mobile phone and personal computer industries. The others, such as education (Morrissey, 2010), are still waiting to be addressed.

[51]We have considered multiple ways of employing the electro-magnetic compass that was first introduced in iPhone 4 and use it to compute the movement vector to compute the corrections for the GPS errors. While this approach is standard in car navigation systems (while the car passes the tunnel and loses the GPS coverage for example), they are difficult to prototype for bicycle riding with limited resources in the lab.

[52]These interfaces can take advantage of the configuration of the public space, visualizing the movement of people on the building facade. Traditionally targeting architecture, situated technologies are based on ubiquitous computing weaved in the physical matter.

[53]There are, however, an experimental approaches to the marketed apps too. Games for Apple's iOS, for example, are released in a first version to the market and then user tested on the real users, where creators observe where they may have made mistakes in design or where the gamers struggle.

[54]Foursquare stimulates users to check-in in places and gather points and compete among the groups of friends. There are virtual rewards for accomplishments, such as for the numbers of checkins at certain places, checking-in at special places and numerous others as well as their combination. Majority of users takes Foursquare as a fun locative game, but does not use it for the discovery and exploration of the cities that much.

[55]The perception field is not necessarily visual, but can be aural or haptic, for example.

[56]Rather than just to make users aware.

[57]Some may argue that this is going against human-centered design, important in HCI (Norman, 1986, 1990), as well as in other design disciplines. I argue the human-centered approach is just too prevalent (Lloveras, 2009).

[58]In Tokyo, "towns" are small administrative districts one level below the "ward".

[59]See latest projects, such as Hadoop, that work with the Big data to discover patterns of behavior and other aspects of online behavior.

[60]These included such as "not being in a hurry", "being in the right mood" and ranged to the pragmatical and technical ones as "must able to understand the interface", etc.

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Appendix A

Additional Navinko Materials

A.1 Early Stage Prototypes and Preliminary User Studies

A.1.1 Design Process - Before the First Prototype

Navinko started initially during brainstorming sessions of spring 2009 semester in KMD. The motivation was Jessica Mantells passion for bicycles and the motivation to augment the bike riding experience with some technology specifically designed to meet the needs of bicycle enthusiasts. There was, at that time, relatively large number of technologies and applications that were relatively close, but none of them that would tailor experience for the riders. GPS systems had screen based interfaces and focused on tracking and nature and their maps did not really contain the information needed for cyclists. Then there was a large pleiad of bicycle computers. Those are also focusing more on hardcore riders and collect data such as distance cycled, or, in case of the more advanced ones even GPS waypoints. Since early into the design process we have also kept social media as one of the foci and one of the core features we aimed to develop.

Navinko was a theme of two MA theses: the first from Jessica Mantell defended in 2010 focused on the design of service and the community and the second one from Yuichiro Kage (also defended successfully in 2010) was focusing on the technical aspects of the iPhone prototype itself. The focus of this thesis is more towards the process of designing Navinko and

the notion of "liminal spaces", rather than Navinko as a product itself. It emphasizes the process and documents influence how the concept of liminal space translates into the design output in the form of prototype, as well as art performance. As I was deeply involved in the project from the very beginning till the present, my experience spans across the whole three years. Navinko was demonstrated at Tokyo Designers Week and also had a performance at Music and Sound Experimental Festival organized by the Tokyo Wonder Site in February 2011.

A.1.2 First Design Concepts

The early ideas revolved around multiple concepts, that included standalone devices working either as interfaces or providing other functionality, such as environmental data collection for specialized mapping related to bicycles. We also entertained ideas connected to wider and bolder services, such as citywide bike sharing that would have embedded technology to ease the pick-up and drop-off process, as well as work on the level of the bike collecting environmental data and finally providing user with a meta-history of her rides during the city, while being able to connect to the other already existing social networks, reworking the bike sharing infrastructures that we can see in many cities around the into the services that would be weaved in into the digital world as well.

While we have brainstormed about ideas for several months, the focus started to emerge: to transform the experience of city riders in Tokyo into one where people can connects with each other and also with the urban landscape in a different matter than until present. Mantell sums up the focus in her thesis and notes that "the goal of this project is to address the individuals experience of the city, and the development and enhancement of the city itself. Through the development of Navinko as a smartphone

Navinko Prototypes		
Prototype Codename	**Date**	**Venue / User Test**
Video prototype No. 1	Summer 2009	N/A
Video prototype No. 2	Fall 2009	N/A
iPhone prototype No. 1 "Wizard of Oz"	January 2010	User test January 26th 2010 in KMD
iPhone App, RC version - RC1	Spring 2010	Pervasive 2010 Helsinki
iPhone App, 1st version	Summer 2010	Tokyo Designers Week 2010, October
iPhone App, 2nd version	Fall 2010	Tokyo Wonder Site, Audio & Sound Experimental Festival 2011

Table A.1: The list of Navinko prototypes. The earlier video prototypes and first iPhone prototype are summarized in Appendices of this thesis, as they are not in direct relation with the concept of "liminal space" and do not directly address the research questions of this chapter.

service for cyclists, the issue of creating a mobile communication interface that is appropriate for bicycle riders as well as social networking and communication tools that are designed specifically with the needs of a cyclist in mind will be explored." (Mantell, 2010) For the purpose of Mantell's research, she formed following research question: "how can urban bicycle riders experience a stronger connection with the city, greater social interaction, and safer riding conditions with low cost and high benefit to the city as a whole?" (Ibid.)

A.1.3 Video Prototypes

The first video prototype, made in summer of 2009 showed the basic idea of user cycling through the city, hearing voice that says the commands on where to go, while the user itself can use spoken commands to bookmark the places. We have decided to call this bookmarking of locations "landmarking".

The second video prototype I focused on the semiotic sounds that would allow users to understand their surroundings through the embedded interface, rather than on the wayfinding function. The semiotic sounds included both hearing the location of places as well as hearing the other users, all using different types of sounds. The sound design itself was entertaining the idea of places having distinct sound based on what type of place it is. The sounds would be based on preconception of existing users knowledge of the environment - such as existing sounds that the Japanese convenient stores use, or so called sound logos. This prototype was the first one that presented the idea of a soundscape that would extend users perception field and reach without guiding and navigation.

The video prototypes were presented to the larger group of viewers, but

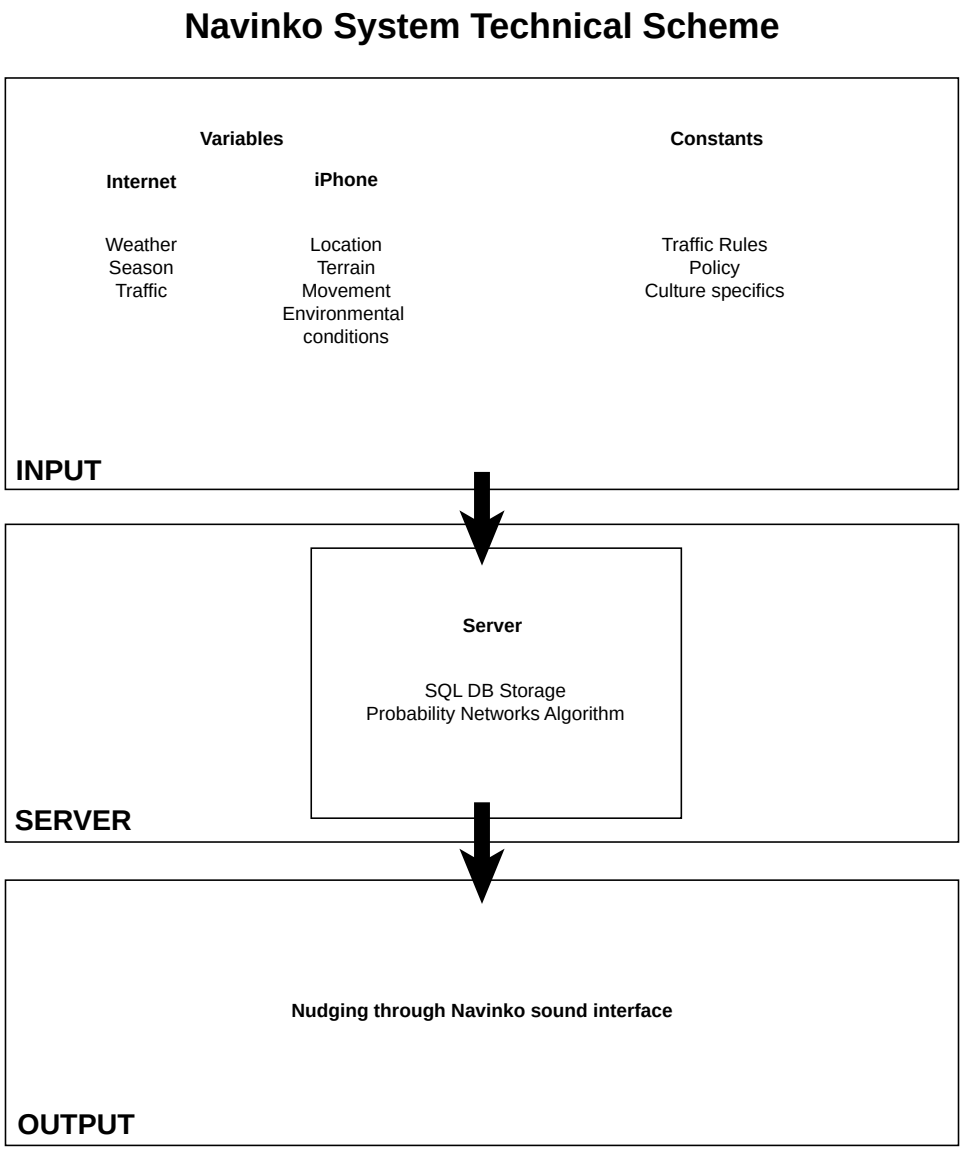

Figure A.1: An early sketch of Navinko system structure. Jan Rod.

for their nature there were no user studies that we would conduct on the formal level besides discussions on the outcome and suggestions of external reviewers.

A.1.4 First iPhone Prototype - Indoor Experience

The third prototype became the first one to be actually introduced on iPhone platform and also the first one to allow user testing that happened on January 26th 2010. It was done indoors in so called "Wizard of Oz" setting when we created the experience that would associate certain parts of indoor places with sounds that represented real world locations in the city. It was using same sounds as we used in the first video prototype, but in addition to the narrative, it allowed us to actually do the first user tests and see what is the response to the sounds itself and their understandability to the test subjects. We let the users walk around the space and play different sounds as they approach the areas. We then conducted the interviews on what was the users general response to the soundscape as well as what was actual rate of understanding the type of the place together with perception of the distance in which they were to the place itself. The places in the city were represented by the pictures of them printed out on the paper and attached to the place, providing a further reference points towards understanding and learning what type of the place the sounds represent.

The response of users was positive. We conducted 8 interviews where the understanding of branded sounds we used for McDonalds shop and Family Mart convenience store was 100 percent and the understanding of the generic sounds designed for yakitori and pet shops was slightly fuzzy (See A.2). The worst results in the meaning understanding were with the yakitori shop, where 5 out of 8 tests subjects could understand that the sounds is associated with food, but were not able to identify the type of the place

User Test No. 1	
Total number of participants	8 students
Understanding of:	
Branded sounds	100%
Generic sounds	62.5%
Direction	100%
Distance	87.5%

Table A.2: First indoor user test of Navinko. Jan Rod.

and 3 users unable to identify the sound at all. The pet shop had better results with 7 out of 8 users being able to identify pets as the type of the place.

The actual positioning and direction of sounds had also generally good response. All of the users could understand the stereo based directions as well as increasing volume during the approach towards the place itself. With positive outcome of the user test, the aim for the next version was to improve the application with real locative functionality and test the interface outdoors.

A.1.5 Release Candidate User Test

The "Release Candidate" iPhone prototype was made during spring 2010 and included the integration with Foursquare mentioned in the previous part of this chapter. It was meant to be fully functional outdoors and it also had the first version of the embedded audio interface. The interface used the temporary version of sounds that we designed and that were meant to be placeholders for the sounds to be designed by professionals later.

This prototype was presented at the Pervasive 2010 (Rod et al., 2010) con-

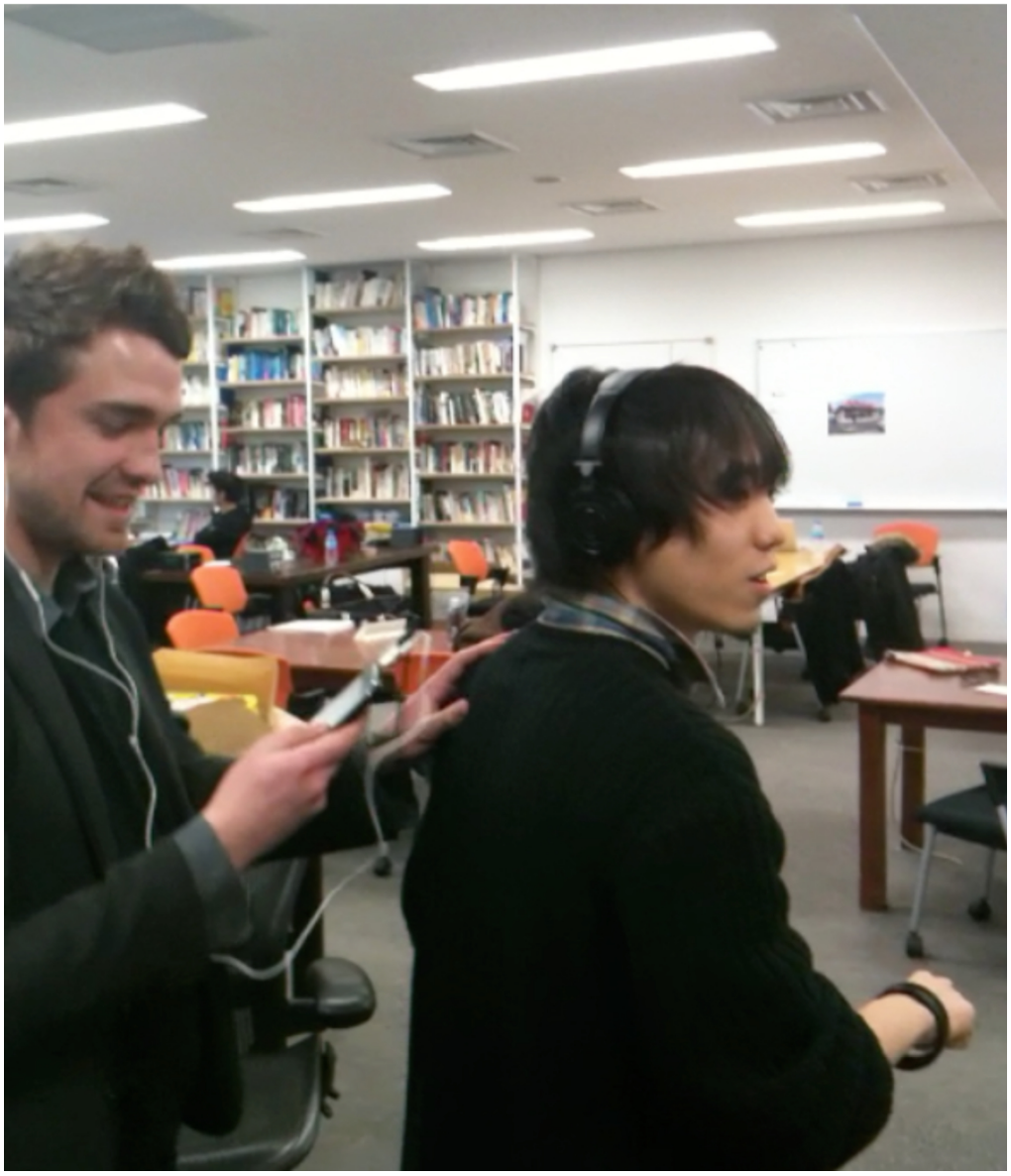

Figure A.2: A participant is being instructed by assistant on the prototype testing. Jan Rod.

ference as a short paper and demoed in the workshop on Multimodal Location Based Techniques for Extreme Navigation. It was accepted positively, with comments focusing on the seamlessness as well as the lightweight design of the interface itself, using only off-the-shelf technology.

The system design of this test itself was straightforward (See A.3). The iPhone logs the sensor data, such as accelerometer, GPS position and electromagnetic compass and sends them over 3G internet connection to the server database in the real time (once per second). The server keeps only the latest version of each users data, flushing the previous values. In the case we would need to log the values through time, we wrote a separate script, that would incrementally log the data into different SQL table and that was controlled manually to prevent the uncontrolled growth of the database while many users connect at the same time and generate large amounts of sensor data. The iPhone client also downloads other data from the server - mainly location of other users that are using the app at the moment and at the same time updates the locally stored databases of landmarks and / or Foursquare POIs.

The client application then separately handles rendering of the sounds. In this version it uniformly changed the volume of the sound as monophonic based on the distance from the POI. The reason for this was that we had difficulties in calculating the vectors that would determine how big is the volume difference for each stereophonic channel. The test proved users can actually say, when they "passed" the POI, but they could not tell the direction, not even while on the move.

The user group was composed of 6 users, university students, that were split into two groups of three and given the application with hardcoded POIs around Hiyoshi station. The first group of the students were briefed about the specific features of the sounds and their meaning and then sent

Release Candidate User Test		
Sounds Types	**Description**	**Reception**
Mixed - rhythmical and semiotic	Musical background with sound effects that correspond with POIs	Negative
Semiotic only	No rhythmical background, all sound have semiotic meanings	Positive

Table A.3: Sound types tested in Navinko application.

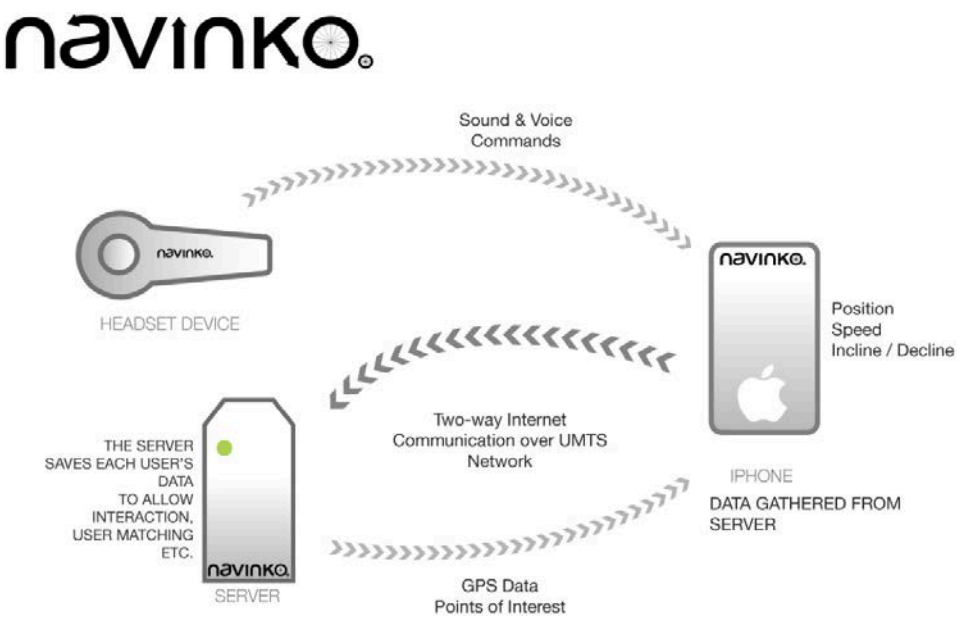

Figure A.3: A scheme of Navinko system design. Jan Rod.

for a slow ride around on the bicycle without any specific goal or given path. The second group was not briefed about the functionality. This prototyping round included several version of the soundscape generation schemes. Rhythmical sounds creating music-like background together with meaning-specific (semiotic) sounds that were triggered while user got near to some of the landmarks. Our approach was stimulated by the focus on creating music-like experience. It turned out that this design approach is confusing the first three test subjects. While we told them "the sounds have meanings", it was hard for them to understand the the rhythmic sounds and subsequently understand the others triggered by the location.

Second group of test subjects, who were not informed about meaning of the sounds and structure of the soundscape, letting them to discover the meaning of the sounds themselves. It turned out that this approach was not good either, as the monotonous rhythm of the music background have blunting effects on test subjects ability to understand and "decode" the meaning of other sounds. One of the participants commented on the rhythmic sounds:

"I was trying to figure out whether I can somehow influence the rhythm as I did not now what should or should not influence it"

While this version focused on testing the actual technology, especially the smoothness of communication with the server and consequent connection with the interface, we were expecting the interaction to work slightly better. It turned out the biggest problem was the occasional delay that was caused by the limitations in the AGPS module, when there is the jitter in the data. Early testers were then reporting, while they knew where the POIs are, that the system was informing them with a lag in time, stating "The App sometimes does not read my position correctly and I have to stop and wait for it to catch up". Through more rounds of testing, we determined that this error, while maintaining general riding speed around 20kmh^{-1}, was about 10-30 meters, meaning that the actual POI already disappeared from users perception field while the sound played, making it very difficult to identify the place itself. Another user noted: "When I go in between buildings, I start hearing messy things. It is like the accuracy drops."

To eliminate this issue, we decided to change the approach slightly and eliminate the problems by experimenting with the speed of movement. It turned out that the reliability of the GPS increases greatly when the speed drops under 10kmh^{-1}, i.e. fast walking pace or jogging. At these speed, the GPS tended to work with higher accuracy and higher update rate, resulting generally in the better experience. In the case of walking (and good conditions of GPS signal coverage), the app was able to play the sounds with the accuracy of roughly 1 or 2 meters, generally within the error margin of GPS technology as such and mis-positioning of the POI data in the Foursquare database. While walking, the test subjects were able to understand better the location due to the increased accuracy and also slower speed of movement meant that the actual place is not disappearing from

their perception field - also mainly due to the greater freedom of movement and agility of a person on foot compared to a bicycle rider.

We therefore moved to the second type of the sound scheme. This included eliminating the rhythmic sounds and using only the sounds triggered by the locations. This approach proved to yield better results with the test groups. At this time, the test subjects were not distracted by the musical background which let them focus more on the actual sounds and percept where do those come from. In this case, the test subjects had no trouble understanding that the sounds are associated with places and because there were sounds only, they could experiment and explore the space by moving around while focusing on the changes in the soundscape. This user test also motivated us towards prototyping the metaphors further beyond the simple volume change based on the distance. It showed us the importance of the algorithms that would make the sounds directional and let users better determine from which place the sound is coming from.

When asked about the enjoyability of the interface and the experience itself, all users users expressed positive feedback with although there were certain problems mentioned above. Importantly, the users from the first test group repeatedly expressed curiosity over the relation between the sound and the location, as they were trying to discover what sound means which location and tried to experiment with finding the exact locations. One user said: "I repeatedly cycled around a block to see if the sounds will be the same and if I can find one place that had sound I liked."

This user test helped the decision to eliminate all the sounds that are not related to locations. We decided to focus on the soundscape only, where, for the time being, the aesthetic side (i.e. enjoyable music experience) was sidelined in the favor of understandability and better user experience. One of the motivations for this decision was that, due to the fact we had no

iPhone App Release Candidate Test - Subjects' Comments	
Test subjects' comments	**Interpretation / Causes**
"The App sometimes does not read my position correctly."	A-GPS update frequency lag.
"It has a low accuracy while riding on the bicycle in small streets."	Combination of the A-GPS update lag & higher speeds. Can be also affected by taller structures around.
"The musical soundscape is confusing"	Mix of rhythmical sounds and semiotic sounds yields confusing results.
"I could not understand the rhythmical sounds"	Rhythmical sounds have no meaning, only to create impression evoking music.
"I cannot understand why is there a rhythmical sounds and then sometimes the sound effect"	The connection between user's actions and the sounds is confusing due to the mix of musical and semiotic sounds.

Table A.4: Second user test of Navinko. Selected comments from interviews conducted with test subjects.

sound designer on our team, we were not able to design sounds that would match together well to create the aesthetically enjoyable experience. Another important finding was that there is a need for the users to be a priori explained about the soundscape and the way the application works, as the experience with it is unique and does not resembles any other interaction paradigms. Most importantly, for the liminal space argument, there were first hints that the soundscape can be stimulative and modify peoples' behavior towards discovery and active use of the space.

A.1.6 Public User Study in Aoyama

The second user test went on to implement findings from the first one. That was mainly soundscape composed of solely sounds related to locations and improved logging and saving users' trips made with the application on. After implementing these changes, we had a version of Navinko App that was releasable and could be tested publicly. Serendipitously, we were offered to propose some collaboration with a public event[61] carried out in Aoyama area of Tokyo. The theme of the event was "Endangered Species" that united locations of shops through various of these animals. Each of the shops had assigned one animal and people could go around and collect the stamps of the animals into the guide book of the event. These stamps were referring to the similar ones that travelers can get when visiting tourist locations within Japan. This was a great opportunity to do larger scale user testing based on the real application of the concept.

The soundscape was designed to match sounds of the animals together with the exact locations of the shops and then hardcoding them into the system. The outcome we hoped for was natural soundscape, laid over the physical space of the city. With all the shops concentrated in a relatively dense area around Omote-Sando and Aoyama Dori boulevards, we achieved to

create a soundscape that resembled the unique habitats of these animals, creating a unique experience by juxtaposing the natural environment of the jungle soundscape, with Tokyo, the most urbanized landscape in the world.

Due to the specifics of the site and the area, such as high density of the shops that were to be included in the soundscape, there was a need to find different approach towards the filtering issue. We have decided to implement new configuration of the interface including variable distance limits that would change the time when the sound appears based on the density of the area. In the case there is just a few shops, user hears sounds from the greater distance, while there is a lot of them, user hears them only when being near. This proved to be very good decision as the final experience was resembling jungle, where the animals are heard from time to time, not continuously in one overloading experience.

The user test itself was composed of survey built in the application itself that users could reply to directly from within the iPhone and logging of the data of their trips, to analyze them later (see table A.5 on page 201) from the server and see the actual usage of the app by single users.

While we were not doing a traditional survey, we were getting feedback on the application the traditional way - ratings in Apple App Store, emails, Twitter posts and other social media channels. The response was generally good, but we also got comments from which we understood that there is a number users who are confused and do not understand the app and the functionality. Probably the most surprising and alarming was a user who reminded us through Twitter that it is illegal to ride a bicycle in Japan while wearing headphones and that we are technically instigating people to engage in illegal behavior when we tell them to put on their headphones while riding bicycles on the street. We were aware of the issue and we have

Figure A.4: The stamps of locations that were matched with animal sounds in the soundscape designed for the event. Jan Rod.

Ride log data sample

id	username	startdate	savedate	filename	time	distance	speed	mode
184	ymdyun	2010-10-31 06:54:04 GMT	2010-10-31 08:22:51 GMT	ymdyun-2010-10-31 08:22:51 GMT	1h 88m 45s	8.31km	5.62kmh^{-1}	FREERIDE
194	Kod	2010-11-01 07:35:39 GMT	2010-11-01 07:52:15 GMT	Kod-2010-11-01 07:52:15 GMT	16m 35s	1.65km	5.98kmh^{-1}	FREERIDE
199	deco	2010-11-01 23:56:58 GMT	2010-11-02 00:01:01 GMT	deco-2010-11-02 00:01:01 GMT	4m 1s	1.17km	17.50kmh^{-1}	FREERIDE
200	deco	2010-11-02 00:01:14 GMT	2010-11-02 00:18:10 GMT	deco-2010-11-02 00:18:10 GMT	16m 55s	4.29km	15.22kmh^{-1}	FREERIDE
202	deco	2010-11-02 04:46:12 GMT	2010-11-02 04:53:30 GMT	deco-2010-11-02 04:53:30 GMT	7m 17s	2.02km	16.65kmh^{-1}	FREERIDE
208	Isshii	2010-11-02 09:58:22 GMT	2010-11-02 10:10:14 GMT	Isshii-2010-11-02 10:10:14 GMT	11m 51s	1.06km	5.36kmh^{-1}	FREERIDE
209	deco	2010-11-02 10:35:43 GMT	2010-11-02 10:49:26 GMT	deco-2010-11-02 10:49:26 GMT	13m 42s	4.03km	17.67kmh^{-1}	FREERIDE
220	Afroblue	2010-11-03 05:12:06 GMT	2010-11-03 06:22:00 GMT	Afroblue-2010-11-03 06:22:00 GMT	1h 69m 49s	0.63km	0.54kmh^{-1}	FREERIDE
226	genyam	2010-11-03 06:46:22 GMT	2010-11-03 07:23:53 GMT	genyam-2010-11-03 07:23:53 GMT	37m 29s	2.04km	3.27kmh^{-1}	EVENT
228	daruman1221	2010-11-03 07:50:38 GMT	2010-11-03 07:59:52 GMT	daruman1221-2010-11-03 07:59:52 GMT	9m 10s	3.06km	20.03kmh^{-1}	EVENT
230	deco	2010-11-04 00:28:59 GMT	2010-11-04 00:48:37 GMT	deco-2010-11-04 00:48:37 GMT	19m 37s	3.99km	12.21kmh^{-1}	FREERIDE
235	deco	2010-11-13 04:24:55 GMT	2010-11-13 05:01:12 GMT	deco-2010-11-13 05:01:12 GMT	36m 17s	17.58km	29.07kmh^{-1}	FREERIDE
242	deco	2010-11-15 03:34:28 GMT	2010-11-15 03:52:44 GMT	deco-2010-11-15 03:52:44 GMT	18m 15s	4.63km	15.21kmh^{-1}	FREERIDE
253	moyuru	2010-11-20 23:34:06 GMT	2010-11-21 00:10:41 GMT	moyuru-2010-11-21 00:10:41 GMT	36m 34s	8.06km	13.23kmh^{-1}	FREERIDE
256	ma5a0s	2010-11-21 00:45:06 GMT	2010-11-21 01:13:29 GMT	ma5a0s-2010-11-21 01:13:29 GMT	28m 21s	5.36km	11.35kmh^{-1}	FREERIDE
258	moyuru	2010-11-23 03:43:33 GMT	2010-11-23 04:13:17 GMT	moyuru-2010-11-23 04:13:17 GMT	29m 36s	4.30km	8.71kmh^{-1}	FREERIDE
260	moyuru	2010-11-23 06:47:43 GMT	2010-11-23 07:17:15 GMT	moyuru-2010-11-23 07:17:15 GMT	29m 30s	7.08km	14.39kmh^{-1}	FREERIDE

Table A.5: Sample data from Navinko log on the SQL server.

Navinko 1st public user test	
No. of downloads	508
No. of saved rides	524
Avg. rides per user	1.031
Avg. ride length	5.20 km
Median ride length	3.23 km
Average ride speed	22.53 kmh^{-1}
Median ride speed	6.57 kmh^{-1}
Average ride duration	17m 33s

Table A.6: Ride statistics of over the period of October 2010. Navinko.

tried to address it previously by referring to bone conductive headphones, a new technology that was just appearing on the market. Bone conductive headphones touch cheekbone in front of the ear and by resonating it, they create a perception of hearing without being loud to users surroundings or covering her ear.

This seemed to legitimately take care of all the possible problems with the regulations, but it turned out that the law does focus so much on the actual obstruction of hearing (ears) that we have successfully solved, but more on the actual phrasing of the word and since bone conductive headphones are still defined as headphones, they are still technically illegal. We had to, therefore, redesign the application startup user flow and implement into TOS that we are aware of the issue that not everywhere there is a legal option how to ride bicycle and use the application and listen to the soundscape. We also started asking users whether they are walking or cycling and the warning was not shown in the time where the user selected walking mode.

Navinko Application accumulated over 500 individual downloads over the

course of the Tokyo Designers Week. We gathered data from users' iPhones to see on the server side users operations and therefore to see the way user interacts with the system and discover the places where the system does not perform optimally and address these errors. This continuous user testing and improvement presents an interesting and somewhat maybe more useful way of testing out the new features rather than typical user testing setups that work in a closed environment. The rollout of Navinko prototype for the TDW turned out to be strategically good move to see the response of the public.

The original idea, overlaying the urbanized city space with a soundscape inspired by jungle to create a stimulating juxtapose, proved to be valid. Navinko was downloaded and used by over 500 people in that period and the response, gathered through the built-in survey tool asking people about their experience with Navinko. The interesting thing that we could see from the data was the one that we suspected from before. The response by walkers to the features of the system proved to be much more positive than the response by bicycle walkers. Walkers were responsive positively both to the question of reliability and understandability of the system and question of ability to find new places. The average combined response to these two questions (numbers 4 and 6 in the survey) was 2.9 on the scale[62] of 1 to 4 (less is better) in the case of walkers and 2.18 in the case of riders. This fact, combined with the expert responses of the ethnographic research has proven that the idea itself, that is the augmented soundscape, works, but is better enjoyed while walking, rather then riding bicycle both for the reason of technology and specifics (maneuverability, time compression[63]). The pedestrians simply had more time, could interact with the system in a more relaxed manner and that allowed them to both enjoy and understand the soundscape better. That was confirmed by the other survey questions, where the pedestrians universally responded better to questions about enjoyability of Navinko as well as about the understandability of the

soundscapes generated by the system.

This strongly suggested that the idea originally devised for the bicycle might work better in a different context of walking. We have started reconsidering the project, but at the same time, we have already applied, and were accepted, to the Experimental Sound and Audio Festival organized by the Tokyo Wonder Site organization. For this performance, we have already planned using bicycles. We decided not to refocus and change, as the way the performance was envisioned would have negative impact on its visual attractiveness.

A.2 Posters, Leaflets and Other Documentation

This appendix contains various additional materials that are related to the Navinko project, such as screenshots from websites where Navinko was featured, printed materials from Tokyo Designers' Week 2010 and Tokyo Wonder Site Experimental Festival 2010.

Survey of Navinko iPhone version 1, 1st public test users	**Avg. response**	
Question	**(on the scale 1 - 4, less is better)**	
	Riders	**Walkers**
Navinko made my ride more enjoyable.	2.58	1.94
Using Navinko enhanced my awareness of my surroundings.	2.87	2.06
It is easy to understand Navinko.	2.13	
It was easy to identify locations of landmarks through sounds.	2.71	2.24
It was distracting to ride a bicycle and listen to sounds.	1.37	N/A
I was able to discover new places more easily while using Navinko.	3.09	2.15

Table A.7: Survey of October 2010 Navinko user test participants.

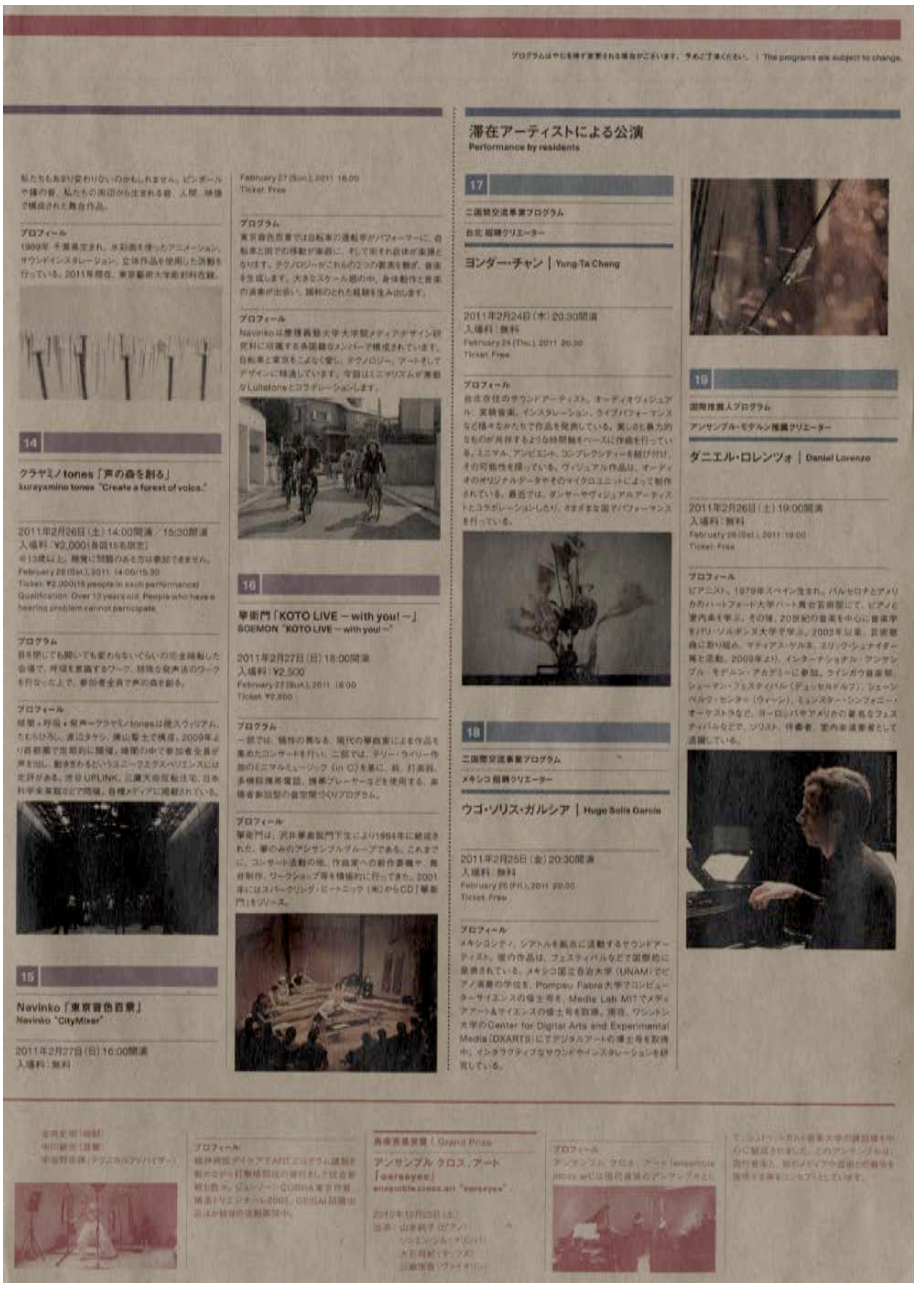

Figure A.5: A flyer and program for Tokyo Wonder Site Audio and Sound Experimental Festival with description of Navinko Citymixer.

Figure A.6: Navinko introduction in the official Tokyo Designers' Week 2010 Guide Book.

TOKYO DESIGNERS WEEK 2010

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Figure A.7: Navinko credits mentioning the project in Tokyo Designers' Week 2010 guide book.

Figure A.8: Stamps of endangered species collected in the Tokyo Designers' Week 2010 guide book.

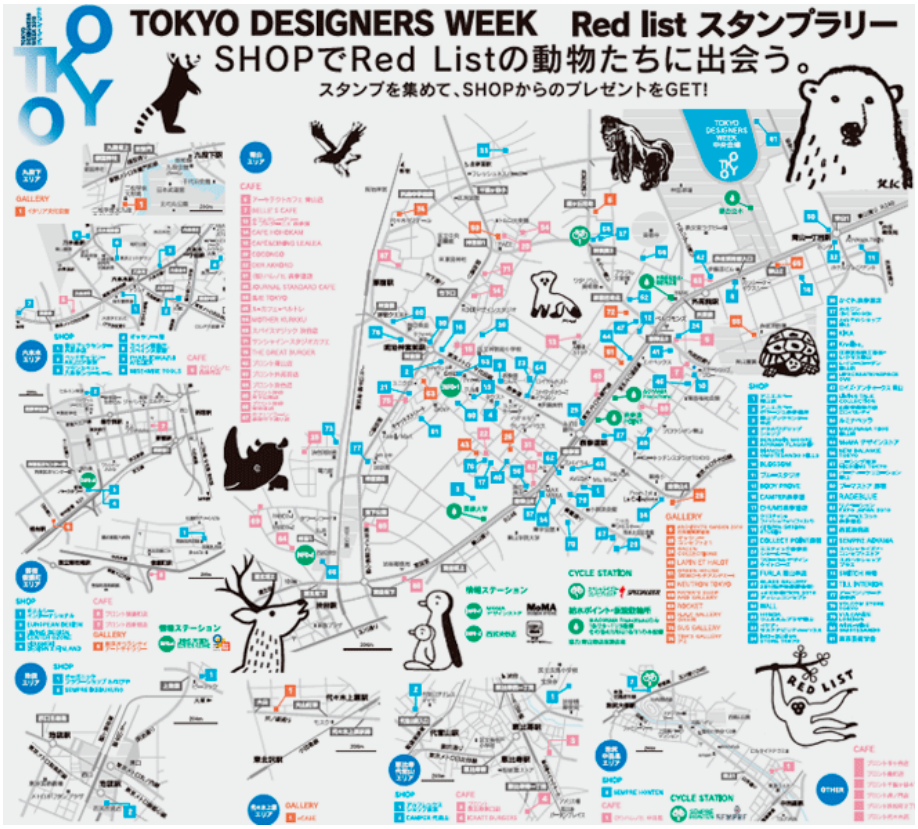


Figure A.9: The map of Shop Exhibition.

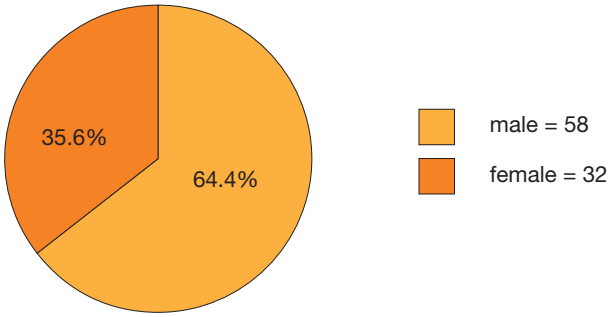
Appendix B

Navinko Ethnography Research

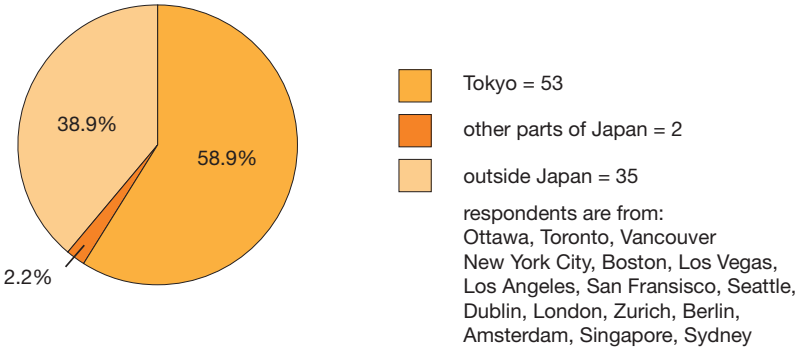
The following survey was conducted during 2009 as a part of the ethnographic study for the Navinko system. The data was graphed by Mantell-Mantell (2010).

Appendix 3 - Survey

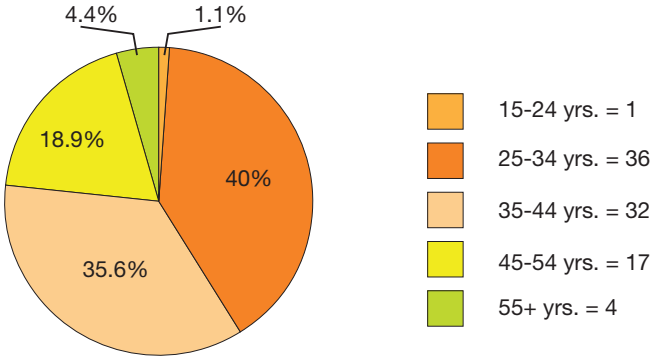
Q1. What is your gender?



Q2. What city to you live/ride in?

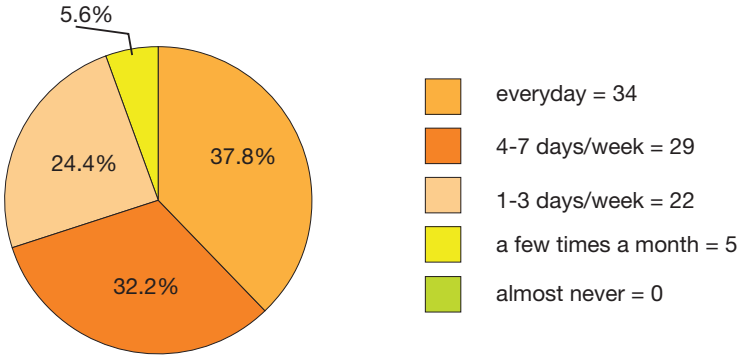


Q3. Please select your age group.

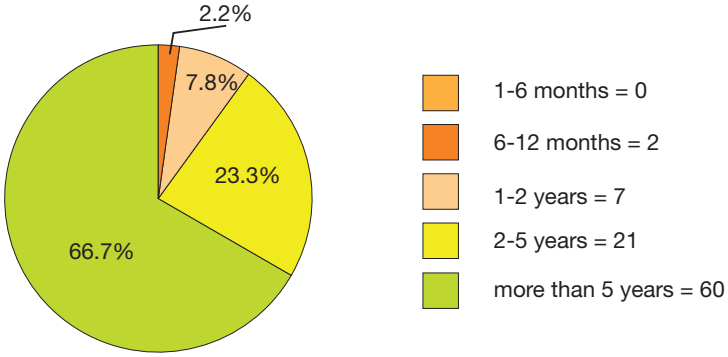


Q4. What is your occupation?
Various responses

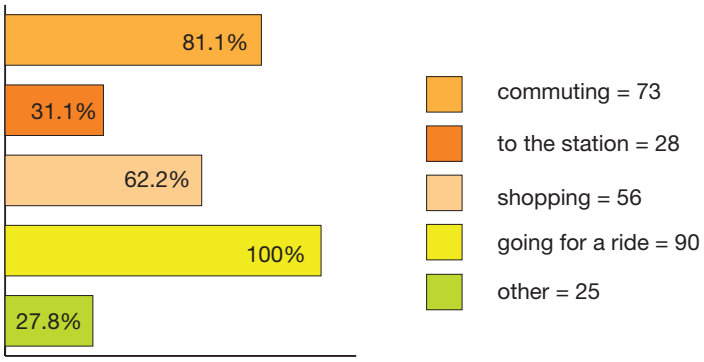
Q5. How often do you ride a bike?



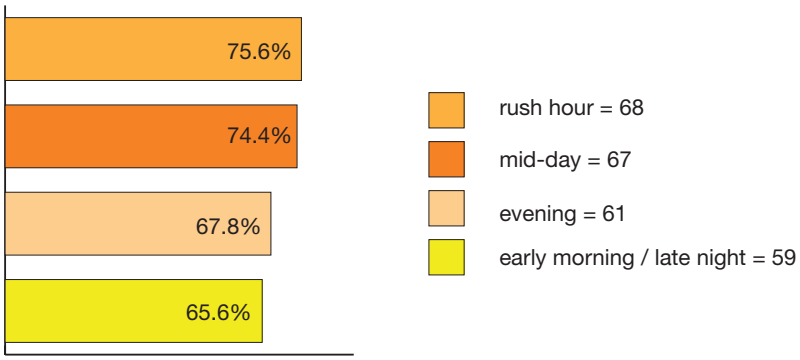
Q6. How long have you routinely ridden a bicycle?



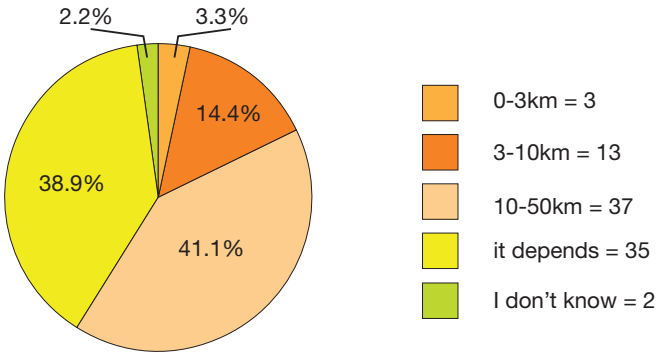
Q7. Where do you ride a bike? (Check all that apply)



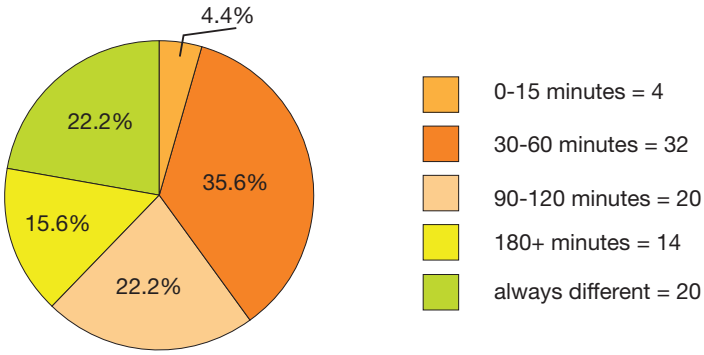
Q8. When do you ride a bike? (Check all that apply)



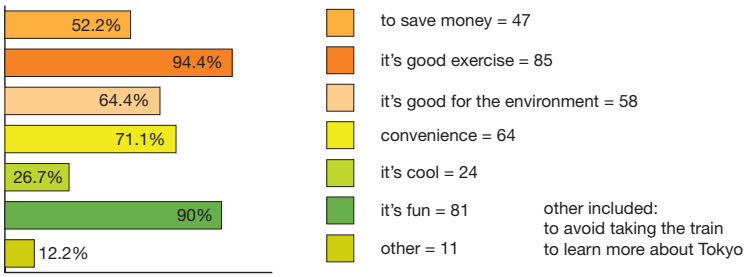
Q9. How many Kilometers do you usually ride in a day?



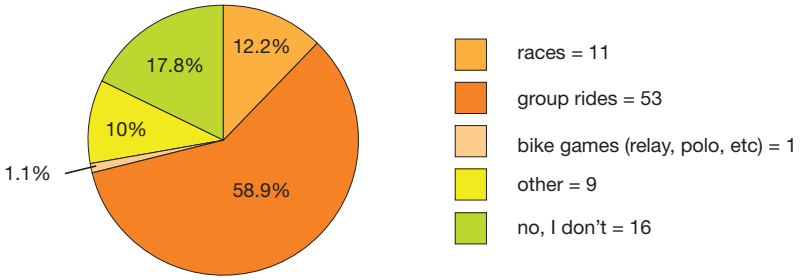
Q10. For how long do you typically ride in a day?



Q11. Why do you ride a bike? (Check all that apply)

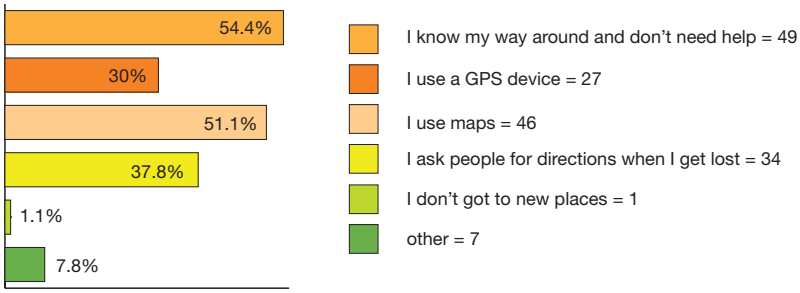


Q12. Do you participate in any of the following?

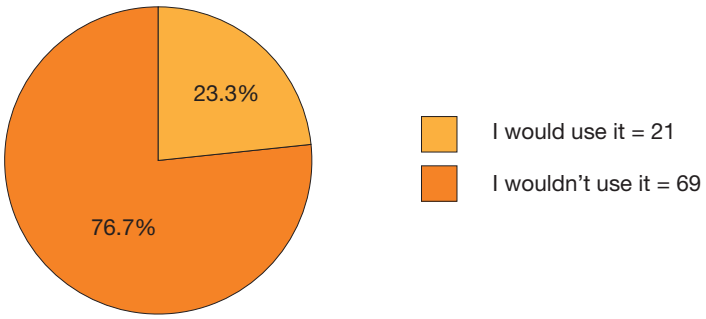


Q13. When riding a bike, do you sometimes…

Q14. How do you navigate around your city on a bicycle? (Check all that apply)

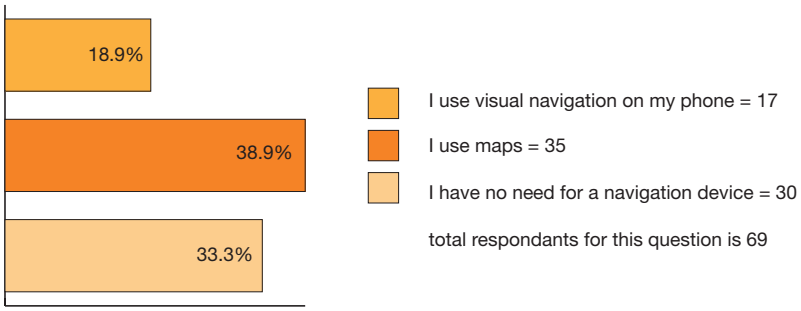


Q15. If there was an audio navigation headset…

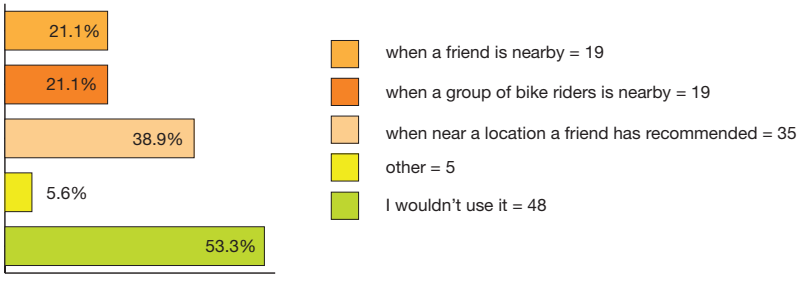


If I would use it is selected, then skip to Q17.

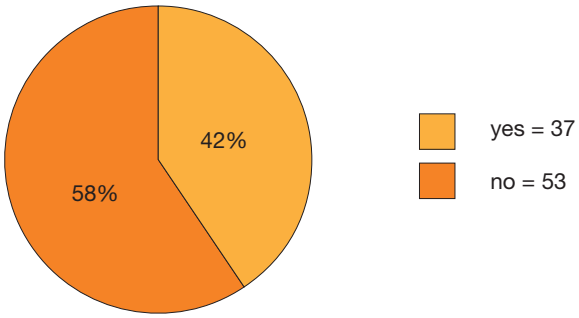
Q16. The reason you wouldn't use audio navigation is (Check all that that apply):



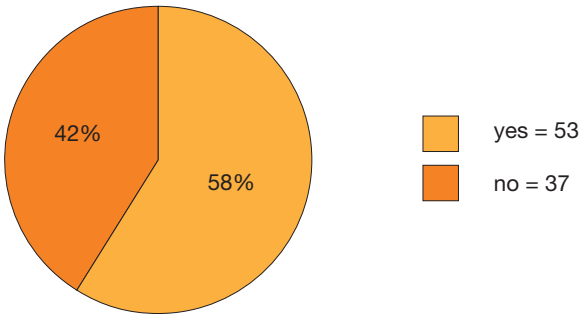
Q17. If this device had other audio notification features, which ones would be appealing to you? (Check all that apply)



Q18. If there was a navigation device that was voice controllable, would you want to use it?

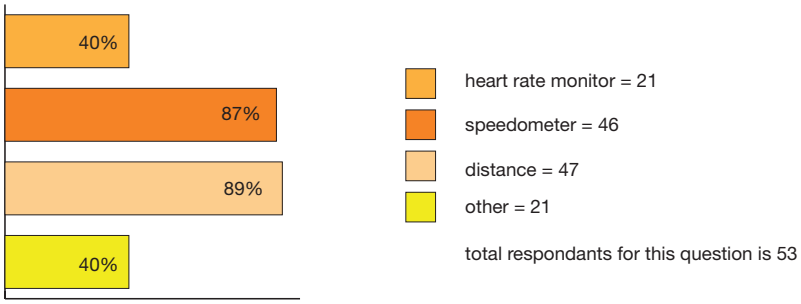


Q19. Do you use a bike computer?

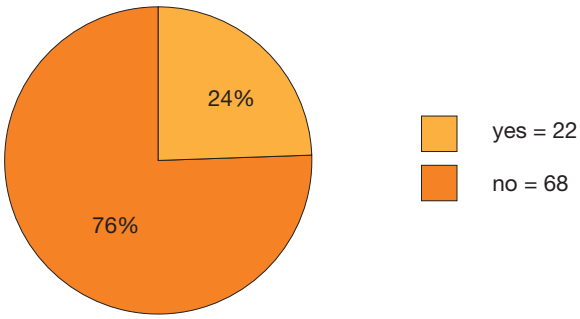


If I no is selected, then skip to Q21.

Q20. If so, what features are most important to you? (Check all that apply)



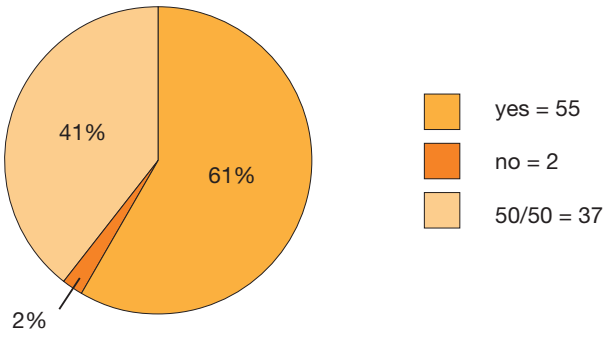
Q21. Do you ever use your cellphone while riding your bike?



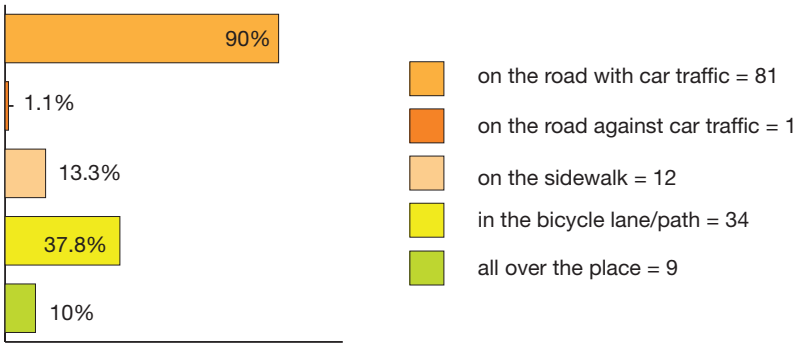
If I no is selected, then skip to Q23.

Q22. If you use your cellphone while biking, do you use it to....(Check all that apply)

Q23. Do you usually ride by yourself?



Q24. What part of the street do you usually ride in?



Appendix C

Previously Published Papers

This section contains papers that were authored or co-authored by the author of this thesis and are being presented as a part of it.

C.1 Navinko - Pervasive 2010 Helsinki

NAVINKO: Audio Augmented Reality-Enabled Social Navigation for City Cyclists

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ABSTRACT
Navinko is a social network and navigation system combined with audio augmented reality for cyclists in Tokyo. It uses mobile devices to store and share users' landmarked Points Of Interest (POI) and interact with other riders while attempting to instigate new types of social behavior, such as clustering the users into bikepools for increased comfort and safety. The Navinko system uses an audio interface for spatial navigation in public outdoor urban areas. We use techniques common to prior human understanding, such as the simulated reversed Doppler effect to indicate navigational variables (distance, direction), providing users in motion with intuitive clues about the location of static, geo-tagged locations, as well as other riders using the same technology.

General Terms
Design, Experimentation, Human Factors, Theory.

Keywords
Audio, augmented reality, navigation, social media, sound effects, aural metaphor.

1.INTRODUCTION

Navinko is an audio augmented reality, social network, navigation system for cyclists, currently being prototyped in Tokyo. It runs on a mobile platform (prototype uses iPhone), allowing users to store and share their landmarks, and interact with other riders. Using this new platform, we are trying to instigate new types of social behavior, such as clustering the users into "bikepools" for increased comfort and safety when riding in city traffic. The Navinko system uses an audio interface for spatial navigation in public outdoor urban areas.

While researching the possibilities of a suitable interface for a bicycle (or a similar personal method of transportation, such as Segway, scooter, electric bicycle, etc.), where both the hands and eyes are constantly occupied [1], we decided on an audio interface. The obvious advantage over a visual interface (i.e. implemented in glasses) is a reduced cognitive load on a user's vision [2], which is needed when maneuvering a bicycle through crowded and high-speed areas. The perceivable concentration of possible points of interest to be tagged and shared between friends on a social network [3] make a visual interface ineffective, especially on a small mobile display. This is mainly due to the high number of POIs in a given area compared to the speed of the user moving on a bicycle. We were thus looking for a solution that would allow us to simultaneously track multiple POIs while indicating their position and distance in space.

We use techniques common to prior human understanding [4], such as the simulated reversed Doppler effect to indicate the navigational variables (distance, direction) to provide a user in motion with intuitive clues about the location of static, geo-tagged locations. The Doppler effect simulation takes advantage of the common semantic aural metaphors we are accustomed to hearing everyday, thus making it easy to distinguish locations in space for users of the

system. This work contributes to a body of work previously done in the specialized field of augmented reality and sound-related projects in general. The novel element is in overcoming some of the weak points of other works previously shown, such as how to indicate the distance and proximity or how to track multiple elements at the same time by replacing the city's soundscape with one created within our system.

2.CITY CYCLING AS A SOCIAL ACTIVITY ENHANCED BY TECHNOLOGY

In most cities, cycling is often seen as an effective way of commuting either the last mile or even longer distances [5]. The Navinko project was conceived with a goal in mind to enhance the experience of present riders as well as draw in new cyclists, using technology.

It aims to merge together practices and technologies already in place, such as social media and mobile devices (Google Maps, Twitter / Google Buzz, Facebook, iPhone or Android smartphones) [6], to transform the city riding experience from that of an individual to a social one - sharing landmarks and being aware of other riders for instance. While researching cyclists' behavior, we came across interesting local phenomena that greatly influence the riding experience. During peak hours in Chinese cities like Shanghai, cyclists used to take over one or two lanes of the main roads due to their sheer volume, but this phenomenon ceased to exist with the recent popularization of cars. It inspired coordinated group rides, such as monthly "Critical Mass Rides." They are organized for pleasure and as a form of activism, while riders mention security as an important issue. Our intention is to create the technology that will allow for a change in the social behavior of cyclists, allowing them reach the critical mass [7], that is to discover each other and join in bikepools for daily commuting. Using already functioning technologies like Facebook or Twitter, we want to reach as many users as possible while at the same time using the existing social and technical infrastructure to the advantage of both users and us as developers.

3.AUDIO INTERFACE & SOUNDSCAPE

One of the obvious issues we had to address was an interface that would be usable even while riding, to inform users of the position of landmarks and other users, about their distance, direction and speed, changing in time. While social navigation is somewhat different from traditional A to B GPS navigations, we also had to address the relatively low effectiveness of text-to-speech engines for spoken directions.

For these reasons we decided to embed sounds in space and use some common aural metaphors to inform users about the spatial position of the sound.

However, up to the present, the work [8] within this subset of AR technologies that use audio has concentrated either on storing pre-recorded or user-recorded data (from projects like Audio Aura, through Tactical SoundGarden, Hear&There and others), or used some kind of speech-to-text-to-speech conversion engines for messages (like Toozla for example). During our research, which focused on bicycle communities, with a bicycle being an example of a modern, ecologically sustainable and overall environmentally friendly means of transportation in a city, we discovered multiple disadvantages of the systems previously mentioned. Mostly this was related to their inability to provide information about multiple targets at the same time, provide easily apprehensible information about their changing distance and direction. Our solution uses a reversed simulated Doppler effect, that indicates the position of a static POI related to a moving user (or any combination of these), to address the above-mentioned challenges of developing an audio interface for spatial navigation.

The Doppler effect itself is a metaphor [9], [5] (in the sense of our understanding of the world described by linguist George Lakoff) that we are familiar with, which creates an easily understandable experience. However, it also puts some demands on the sounds "emitted" by the POIs. These sounds must be continuous and there

is an arguable need for their previous semantic association (for example branded sounds) with the POIs. A benefit that this solution brings is that it is possible to track multiple POIs at the same time, while still being able to distinguish their direction and distance, creating an arguably easily understandable interaction. On the other hand, due to the nature of the sounds needed for the system to perform optimally, these are arbitrarily assigned to the POIs, without a necessary semantic relation to the actual POI itself.

We argue that such a system introduces an innovative technique to the debate on possibilities of using audio systems for navigation and interaction within space. It also addresses some issues that have been common to the majority of other audio AR projects - how to indicate the distance and proximity, how to track multiple elements at the same time, but also issues related to the use of specific means of transport - cyclists cannot look at the display of a handlebar-mounted device and interact with it.

The demonstration of such an interface, where the essential element is the user moving on the bicycle is arguably difficult in an indoor exhibition environment. Therefore, we intend to concentrate on the interface demonstration, leaving out the GPS and other elements and substituting them with different technology for tracking a user's position better suited to indoor use. The users will be equipped with earphones while walking around the space, experience the interface in simulated conditions. The speed of the user will differ from the intended condition, but concluded experiments have proven that the interface works (i.e. is easily usable) by users even while walking.

4.CONCLUSION

Navinko builds upon several practices of the locative media field as well as existing social media technologies to enhance the experience of urban riding as well as instigate new types of social behavior, such as "bikepooling" for increased safety of riding in the streets. Being designed for use on a bicycle, there is a need for a different type of user interface, other than the use of a screen. It uses audio augmented reality based on common aural metaphors, such as the Doppler effect to determine the position of users and landmarks in space. Such techniques overcome some limitations of conventional, spoken navigational systems, such as relatively slow information delivery or inability of distributing information about multiple points of interest at the same time. Navinko uses sounds, rather than speech, that are assigned to a place, creating an audio layer placed over the regular soundscape of the city.

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C.2 From Agency and Subjectivity to Techno-Animism - Digital Creativity Journal Paper, 2010

PHENOMENOLOGICAL AND STS (SCIENCE TECHNOLOGY STUDIES) APPROACH TO DESIGN OF LARGE TECHNO-SOCIAL SYSTEMS: FROM AGENCY AND SUBJECTIVITY TO ANIMISM

BIOGRAPHY

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ABSTRACT

The social, ecological and technological challenges starting on the scale of a small scale city block to the megapolises and further, force us to rethink the user agency in design. What is needed is a Copernican Revolution that will question the centrality of the user and the human and offer a more balanced model for interaction between different agencies. that is more sensitive to the issues of sustainability, co-dependence and symbiosis, which we face within such complex and hybrid systems. One way to go is to rethink the early phenomenological concepts of a subject that is more tightly connected and even defined by its environment (Lifeworld, Dasein). Another approach is to thematize the possibilities and limits of nonhuman agency and define design in terms of creating new networks and assemblages as described by STS and posthumanist philosophy.

INTRODUCTION

From early GUI and VR to tangible interfaces, ubiquitous (pervasive) computing and next-generation post-WIMP interfaces, design theory tends to concentrate on the technological challenges while taking for granted the concepts of the user, the human and the subject as something rather non-problematic, stable and intuitive. The concepts of the human and the subject however were severely contested in the 20.century by philosophers such as Martin Heidegger [1], Michel Foucault [2], Roland Barthes [3] and by later posthumanist critiques inspired by Donna Haraway [4] and Katherine N. Hayles [5]. These concepts are even further eroded by the recent turn towards objects, materiality and ontology in speculative realism and object oriented philosophy (Graham Harman [6], Iain Hamilton [7], Quentin Meillassoux [8]) and by various views on non – human agency in Science, Technology and Society (STS) studies (Bruno Latour [9], John Law [10] and Andrew Pickering [11]).

All these theories challenge the unreflected notion of subjectivity as they open a different view on material agency of things, objects and environments which design practice so ceaselessly embrace and experiment with. We are witnessing the momentum for a

valuable interdisciplinary dialogue in which design and philosophy can collaborate for the mutual benefits of both. Contemporary continental philosophy and STS redefine the design practices vis-à-vis ecological, economic and political crises. They bring a better understanding of the stakeholders' relations and their heterogeneous interactions and provide a more informed discussion on the limits and possibilities of the humans facing such complex systems. Design practices on the other hand provide a much needed experimental method and framework for humanities and social sciences research that reflects upon the present conundrum of actor-networks, various ideas on flows, spheres agency and materiality.

What are the various views on subjectivity and agency in the present design theories and practices? Can the more neutral concepts of agency and actors instead of users and humans offer more space for discussion of the present hybrid and complex situation with many stakeholders and interacting systems (STS approach to design represented by Latour & Weibel [12], A. Yaneva [13])? Should we maybe rather reconsider and revive the original concept of interaction between humans and the world in phenomenological terms (Winograd & Florres [14], Dourish [15]) or, maybe even use a stronger notion of "sociality" inspired by pragmatism (Hughes [16], Pinch & Bijker [17]) and drop the idea of objects as meaningful outside interactions with humans? Would these changes in our perspective on subjectivity, agency and materiality help us to face the present challenges and crises? Will they just deepen the depersonalization and the loss of the political, cultural, the "meaning" creation dimensions of our human condition and social existence?

SHORT GENEALOGY OF THE HUMAN & USER CENTERED DESIGN

Starting with ergonomics, industrial, machine and product design, our practices and theories of design were always closely linked to some strong but unreflected notion of human subjectivity. Phrase such as "human factors" (science, engineering, integration)" [18], "humanization of technologies" [19], "responding to user needs" [20], "augmenting human intellect" [21] [22], "man-machine symbiosis" [23], "man-machine graphical communication system" [24] present some of these early views on humans interacting with machines and computers. The words "human" and "man" are often used in the early documents, manifests and memoranda before 1980s even when they don't embrace individuality and humanist ideals but standardization and ISO forms [25].

The word "user" is a more common trope for describing various interfaces and interactions with machines and computers only after 1980s. It is a paradox that while the early concepts of the human in relation to machines, technological systems and computers often emphasize generalized issues of compatibility, health, productivity and safety of the subject, the later more neutral concept of the "user" in information, interaction, graphic, interface, experience, emotional and user–centered design emphasize the more soft and hard to measure "user experiences" [26], "user satisfaction" [27] and various often subjective values of usability.

Whether we speak of men, humans or users, the unreflected theory of the subject still bears certain expectations that influence the design processes. HCI and design concepts of the subject work with an idea of a human being that is influenced mainly by the cognitive sciences, research in AI, philosophy of mind, and after the 1980s also social and cognitive psychology. Design is meant to enhance, augment and extend the cognitive abilities of an individual and completely autonomous subject, and to better interfaces support various user experiences via interfaces. The user is always in control, he or she is autonomous,

independent and endowed with agency to which we have to accommodate the outside environments and the tools. Even when designers try to criticize the phrases such as "user" or "consumer", they still use the romanticized and enlightenment ideal of a human being endowed with agency that gives meaning to everything else. In terms of this view on subjectivity, HCI and design theory can be considered simply the latest incarnation of humanism and the enlightenment ideals or progress in terms of their theory of subjectivity. We can clearly see this in emotional essay written by Don Norman "Words Matter. Talk About People: Not Customers, Not Consumers, Not Users" [28] where he warns us against the dangerous depersonalization of humans in the age of future machines that Bruce Sterling calls "biots". Against this Sterling's bleak vision of the future in which it will be impossible to make a division between the person and the device, between the human and the machine which both become biots, Norman places his 21. century essay on the dignity of men that paradoxically raises the problematic value of power at the end: "Words matter. Psychologists depersonalize the people they study by calling them "subjects." We depersonalize the people we study by calling them "users." Both terms are derogatory. They take us away from our primary mission: to help people. Power to the people, I say, to repurpose an old phrase. People. Human Beings. That's what our discipline is really about... Time to admit that we are people, that we design for people.... All of them are people. All deserve their share of dignity. Their roles can be specified in other ways. It is time to wipe words such as consumer, customer, and user from our vocabulary. Time to speak of people. Power to the people."

TWO APPROACHES TO THE LARGE TECHNO-SOCIAL SYSTEMS: STS AND PHENOMENOLOGY

The limited and naïve view of the user as a human whose abilities and experiences we plan to enhance with technology may work well in the case of small scale projects that involve limited numbers of actors so that everything can be staged to accommodate the proposed vision of interaction. This model however does not work in the case of large networks and techno-social systems with many heterogeneous actors in which we experience complexity and emergence. Environments embedded with intelligence and sensing thanks to the various information and sensor technologies such as envisioned by Haque [29] force us to redefine our view of what is agency and how to design for complex system involving large groups of users, stakeholders, heterogeneous environments and institutions which are the reality of our world today. In order to address such large socio-technical systems which are designed with the help of ubiquitous (pervasive) computing and next-generation post-WIMP interfaces we have to redefine our understanding of the subject and agency. We will start with the STS approach that leads to a non anthropocentric and post interactive understanding of design and then continue with the phenomenological approach which proved many times to be a source of inspiration for HCI development.

STS APPROACH: POST-INTERACTIVE AND NON-ANTHROPOCENTRIC DESIGN

The biological, social, political, geographical and various other actors and their interactions are becoming part of almost every design problem in recent years and the goal is to create solutions that affect whole ecosystems, habitats and institutions rather than just building a tool for a group of users or for an individual person. The anthropocentric bias expressed in the naïve view of user subjectivity is making way to more complex understanding of interaction involving different systems that form our cities, the globalized society but also the larger ecosystems of our planet. In order to understand and act in such complex world

we need to support more passive, empathic and reflective goals and tasks rather than interactivity per se. We need more means to reflect upon such interconnections with the environment in a sense of our habitat but also in a sense of our political, social and economic milieu and become aware of their limits.

We expect our technologies to help us understand and manage the different limits of our biological, social and political existence rather than to support the narrow techno-optimist forms of enhancement and extension. The technologies are slowly becoming more a means for reflection, persuasion, empathy and even moral improvement rather than only means of immersion, interaction and transformation. In the most obvious cases this involves managing our physical fitness and health or monitoring and warning us against energy consumption or other excesses [30].

The design for this "post-interactive" era simply prefers monitoring, visualizing, reminding and persuading as the main functions of the new tools and applications working with large numbers of human and non-human users (institutions, stakeholders, environment). The goal is to create a new types of local and global awareness and support various identities and communities in the contexts of our neighborhoods, cities, countries or even the whole planet and the biological habitat.

This plurality and design do not include only humans but more importantly all kinds of entities with which we interact and build what Bruno Latour calls "collective experiments", "progressive compositions", "provisional assemblies", "versions of collectives" or even cosmopolitics [31]. By experimenting and creating new equilibrium between human and non human actors we create very complex, emergent and symbiotic relations. Design in this non-anthropocentric and post-interactive sense is more about symbiosis rather than control and it is reviving some of the original visions of the early pioneers of the interactive broadband society, concepts such as "man - computer symbiosis" in Licklider [23] or Engelbart`s idea [22] of "augmenting" not only the human intellect but also our institutions and society and transforming them into "new species".

PHENOMENOLOGICAL APPROACH: DESIGN AS CREATION OF TECHNOLOGICAL LIFEWORLDS

Tradition of HCI has on many occasions turned to phenomenology to understand the relations between human cognition and the world of objects, things and nature. The main purpose of these explorations of phenomenology has been the need to create interfaces that would feel natural for people to use and enable them to easily interact with machines, while using metaphors we employ in real life. Nowadays we have to change this goal into interfaces that not only feel natural to humans but which also remind humans of their interdependence with nature and the world outside.

Winograd and Florres [31] were the first to use the phenomenological theory in the field of HCI. In their book Understanding Computing and Cognition, they have analyzed how we use metaphors common in our everyday understanding of the world (that is the world outside the computer screen) while thinking and designing computer systems and applications. One can object that middle 1980s technologies, especially interfaces looked very differently (early available GUIs, absence of massive networking) from what we have now but the core idea has prevailed in the HCI theory until today, it even expanded and

perfected by many great thinkers (Dourish [32] and others) as well as in the practice (Garrett [33], Goodwin [34]).
The interpretations of Husserl's and Heidegger's phenomenology in HCI take almost exclusively subject (user) as the point of departure for further thinking about the interaction. We need to rethink this starting point in order to approach the design of large techno-social systems that are more complex in this respect. We need to acknowledge that computers and devices evolved from standalone objects through networked machines into multi-purposed mobile tools that are part of our everyday lives and and create large computational grids connecting people with everything around. Convergence of various technologies, including physical objects with sensing and intelligence that are becoming part of this grid creates a new type of aTechnological Lifeworld to which many people are simply born.

The design in this view is an activity that creates a technologically extended Lifeworld, a rich environment that allows mutual interaction of subjects that are part of it. We can not think anymore of self-sufficient and independent users/subjects that are individualistically oriented and not aware of this complex interdependence with their environment.

The concept of the Lifeworld comes from the 20th century philosophy of Husserl and Heidegger [35], [36], [37] and it was a critique of the objectifications and scientific and technological appropriations of the world. Technologies at that time where still rather robust and visible, not personal in most cases and not part of everyday lives and experiences of the people. Today's invisible and embedded technologies that are immersed in every aspect of peoples lives offer a possibility to extend the Lifeworld in terms of a dialectical relationship of socially conceived of space as something which is actively produced, rather than as a relatively inert container to enhance comfort and optimization as the user-centered approach to the technology continues to hold sway. The various natural and technological agencies in this milieu allow the subject to evolve by creating new types of relationships to the objects and people around. These new technologies offer a possibility of a flow, exchange of meanings, sensory data and information between different agencies. This flow that is created by embedded technologies and ubiquitous computing are like phenomenological horizons that serve the subject to create a meaningful experience of his (technological) Lifeworld.

INTERACTION AS FLOWS AND UNFOLDING OF HORIZONS
In order to understand the interaction in terms of flows and horizons we have to explain some of the basic insights of Heidegger's and partially Husserl's phenomenology. The concept of being immersed in the world (Dasein) is all about processes of relating and emerging as temporality of movement through the world as a space of possibilities. This being in movement and constant relations to the world is not a subject nor object of anything but "being-in-the-world" that creates his or her identity by constant process of interaction with the world and its objects. In such world, there are no passive objects occupying silently the space but they are always part of our lives and experiences.

The perfect technological object that explains such interaction and exchange in a technological Lifeworld are what Bleecker calls "blogjects"[38], objects embedded with sensors that participate on the meaning creation and exchanges in the information space. As Bleecker [12] points out, they are not just 'publishing' some information gathered through sensors, but that they do act as "producers of conversations that are relevant to

others" and they are, as Bleecker calls them, 'first-class citizens'.The philosophical concept of Lifeworld as conceived in the 20th century phenomenology puts the subject in the center of meaning creation because of its ability to communicate and create meaning. Things, objects and nature are pointing towards this meaning creation being as passive participants. The technological Lifeworld questions this subject/object division by emphasizing the inseparable connection between us and the world in which objects and tools communicate and create meaning. The pervasive computing are means of translation of meaning between humans and non-humans, they translate flows , unfold of horizons via various agents.

The technological Lifeworld connects the phenomenological insight about the importance of things in the creation of meaning related to our lives with the basic function of pervasive computing and objects embedded with sensing and intelligence that are actively participating in the creation and exchange of meaning. The pervasive computing is only first step and we can already see a successful efforts in its completion. The goal of such design is not only to subsume computers into things, to equip things with some sensors that will broadcast data, but to make things that 'are' computers. MIT Center for Bits and Atoms led by Neil Gerschenfeld [39] presented materials able to do some basic computational functions with very little energy consumption. The blurring of the distinction between the thing and the computer, between the physical and the digital,creates the technological Lifeworld.

CONCLUSION: STS AND PHENOMENOLOGY AS A RETURN OF (DIGITAL) ANIMISM

Environments enhanced by information, sensors and other embedded technologies form a large techno-social systems that simulate in many ways the old animistic belief in objects having an agency and life, objects being able to take an active role in interacting with humans. Design for such environments should not target only to humans, like in human-centered approach, but rather concentrate on the flow between the both human and non-human actors, as well as between the environments and their elements and finally between environments themselves. To understand these subtle exchanges between different actors we can think of them in terms of flows that express not only spatial but also temporal distance, the time we need to create a more tight, intimate and everyday relations and symbiosis with new elements, actors, environments.

Where human-centered design works with the dualism of user needs opposed to the world of objects and things that resist, here we are constantly interconnected and influenced as part of the flow within a system of networks and interactions. The design becomes a type of digital animism close to what discussions describe as RBI (Reality Based Interaction [40]). This interaction is a vision of ubiquitous computing "driven by the possibilities of the future" [41] rather than by the problems of the present or past. The aim of such system and interaction is to instigate thinking about different possibilities, to contemplate about the design as part of creation of such large information systems and to reflect the possibilities that these technologies bring.

In this sense we are not designing just new types of objects, but rather a new type of ecologies and symbiotic relations between different actors and agencies. We are creating a technological Lifeworld in which design is like practicing digital animism rituals. It is a non-anthropocentric design that takes seriously into account the interests and agencies of non-human actors. It is a design which values reflection as much as it values interaction and creation of new networks and connections.

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