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Empowering Mobile Art Practice

A Recontextualization of Mobile and Ubiquitous Computing

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Summary

Creating art with mobile phones in public spaces is an emerging form of artistic expression. This dissertation investigates the design and use of mobile art applications for creating and sharing interactive art experiences in public spaces. It explores new ways of deploying mobile and ubiquitous computing for art making that fosters creativity and community.

This is done by developing a series of novel prototype applications, with a focus on multimodal interfaces that are put into use in authentic environments for validation by real people. The approach is to couple an artistically motivated design and innovation process with mobile, web and public display technologies, in order to explore the prototypes that build the empirical framework of this research.

Multimodal interfaces address many of the human senses, such as seeing, hearing, touching; they thus provide powerful user experiences. Combining spaces with different modalities provides new possibilities for real-time interaction and engaging experiences. But there is a problem in that little is known about how to design multimodal interfaces and systems to work in the context of the city as digital interface, especially how to enable participatory, real-time interaction in urban space to foster creativity and togetherness.

The resulting mobile art applications signal a new era in digital creativity, as they show the strengths of future mobile interactive platforms. The key points are providing engaging experiences of mass participation both locally and physically distributed; enabling creativity; and promoting real-time interaction not only between 'people and people' or 'people and machines' but also between 'people and things', such as nature, buildings, objects and the physical environment generally. These forthcoming approaches will lead to designs and implementations of new mobile interaction platforms, which eventually will lead us to new leisure time activities, such as creating and sharing art experiences in public space, but also to new ways of living an art- and culture-inspired lifestyle—empowering mobile art practice.

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Helsinki, Finland
May, 2010

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Introduction

1 Introduction

This dissertation investigates the design and use of mobile art applications for creating and sharing interactive artistic experiences in public space. It explores new ways of deploying ubiquitous technologies for art making that foster creativity and community. This is done by developing a series of novel prototype applications, with a focus on multimodal interfaces that are put into use in authentic environments for validation by real people.

Multimodal interfaces address many of the human senses, such as seeing, hearing, touching; they thus provide powerful user experiences. Combining spaces with different modalities provides new possibilities for real-time interaction and engaging experiences. But there is a problem in that little is known about how to design multimodal interfaces and systems to work in the context of the city as digital interface, especially how to enable participatory, real-time interaction in urban space to foster creativity and togetherness. Lehmann states that in an open-situated context, individuals can discover and use their creativity when perception, action and observation are enabled between people - as they are in urban locations where social and creative processes are interlinked (Lehmann 2008). To explore such issues, designing new forms of interfaces and media practices through the deployment of information and communication technologies is valuable. How can we combine the Internet, mobile technology and public displays to form new interfaces and interactive applications that allow the urban reality to be changed through temporary interventions and newly formed communicative processes?

Urban computing is an emerging interdisciplinary research field that studies the interaction of the urban space, people, technology and information. It is driven by two trends, urbanization and rapid deployment of computing infrastructure in different forms in the urban space. Large public displays are being installed indoors and outdoors for informative and commercial broadcasting. Many different types of sensors, for example traffic counters, micro weather stations and surveillance cameras, are becoming more and more common in urban space. Often, their deployment is driven by technology, and thus human factors are not adequately considered; nor are creativity

and art given a crucial role. How can design knowledge and artistic practice make a difference in providing rich and meaningful experiences to users through such technologies? My approach in this dissertation is to couple an artistically motivated design and innovation process with mobile and web technology, in order to explore a variety of prototypes. The resulting mobile art applications show how ubiquitous technology can be deployed to create novel experiences, new art-making processes and new forms of digital art production in public space. The applications inform future design of new types of artistic and social activities that may eventually become everyday actions of creative expression and exploration.

Wireless technology, in particular the mobile phone, takes a central role in this research. The mobile phone is traditionally known as a communication device but has been used in recent years as a gaming device, too. Turning the mobile phone into an art tool, however, is a rather new idea. Creating art with mobile phones in public spaces is an emerging form of artistic expression. Due to its rich functionalities, mobility, connectedness and ubiquity, the mobile phone provides many new opportunities to discover and create novel forms of artistic practices and engaging experiences.

In many ways, this thesis reflects my vision of future ubiquitous technology, from an artistically motivated design perspective. By describing possible design directions, future developments, strategies and their implications, the presented knowledge aims to be useful as a conceptual map as well as a tool for future interface and interaction design in the field of ubiquitous computing and mobile interactive systems, particularly multimodal art tools. The gained insights inform future design of multimodal interfaces of pervasive applications in urban spaces. A minor goal of this research is to strengthen and expand understanding of the arts and design in the field of mobile interaction and multimodal systems design as a means for expression and exploration.

This dissertation presents four mobile art applications that aim to enable individuals to experience space and time in the physical environment in new ways and aim to let them draw inspiration both from the artistic process and the final artistic outcome. The applications show how we can engage not only with the visual but with the

auditory, kinesthetic and tactile modalities of multimodal interfaces, as part of ubiquitous computing systems.

The following four mobile art applications build the empirical framework of this research. They are listed in the same order as they were built. The found key concepts and knowledge gained from building one application contributed to development of the next application.

Figure 1. MobiLenin application

MOBILENIN couples multimedia art with a nonconventional distributed human-computer interface for multi-user interactive entertainment. It allows a group of people to interact simultaneously with a multi-track music video shown on a large public display, using their personal mobile phones to effectively empower the group with the joint authorship of the video (figure 1). The underlying system is realized with a client-server architecture that includes server-driven real-time control of the client UI to guarantee ease of use as well as a lottery mechanism as an incentive for interaction. MobiLenin offers a new form of interactive entertainment for pubs and other public places, and the underlying architecture provides a framework for realizing similar installations with different types of multimedia content.

MANHATTAN STORY MASHUP (MSM) melds together the Web, camera phones and a large public display into a collaborative street art authoring system (figure 2). The implemented large-scale pervasive game introduced a new form of interactive storytelling that lets an unlimited number of players author stories on the Web, while a large number of players illustrate the stories with camera phones in real time. The client-server architecture allows high scalability in handling Web and mobile users within the system simultaneously.

Figure 2. Manhattan Story Mashup at Times Square

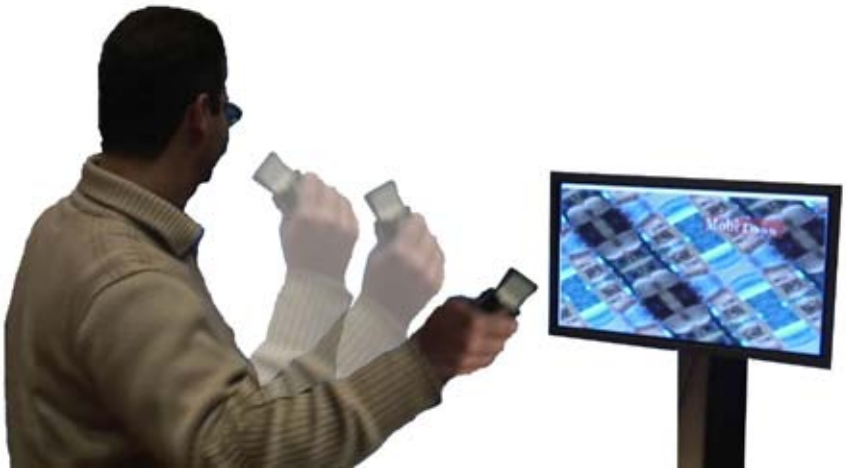


Figure 3. MobiToss – throwing a video to the large screen

MOBITOSS is an application for creating and sharing mobile multimedia art with an off-the-shelf mobile phone equipped with built-in accelerometer sensors allowing gesture control. The user first takes a photo or captures a video with the phone and then, using a 'throwing' gesture, transfers the clip onto a large public display for instant viewing and manipulation by tilting the phone in different directions (figure 3). The system augments the user-created clip with other items such as music or brand labels, and the encoded clip is automatically sent back to the phone as a personal artifact of the event. MobiToss could be deployed, for example, in clubs, in pubs and at concerts as a participatory VJ tool.

Figure 4. MobiSpray in action

MOBISPRAY provides an interactive system for creating ubiquitous ephemeral digital art. The mobile phone is employed as a virtual spray can to spray dabs of digital paint onto the physical environment via large-scale projections (figure 4). The gesture-based control of the mobile phone provides a natural pointing mechanism for the virtual spray can. A connection over WLAN is used to exchange real-time motion data between a mobile phone and a server run on a laptop that renders graphics in real time.

1.1 THE STRUCTURE OF THE DISSERTATION

This dissertation contains two parts, the introduction and the set of articles. The introduction consists of six chapters, which are described briefly in the paragraphs below. The set of articles starts with chapter 7. A brief overview of the articles is provided in section 1.3.

1 INTRODUCTION provides, first, an overview of the aims of this dissertation and its motivation. It describes four mobile art applications that build the empirical framework of this research. Second, the introduction presents the research questions and their core focus of exploration. Third, it introduces the articles and discusses how the work described in each is linked with the literature. Fourth, it reports the early inspirations of this dissertation.

2 INTELLECTUAL CONTEXT reviews related topics and concepts and discusses their importance in regard to multimodal interface design and mobile art applications.

3 TECHNOLOGY reviews major technology components and concepts relevant for designing multimodal interfaces and interactive applications having mobility as a core component. It also provides an overview of current software tools useful for building such interfaces and applications.

4 DESIGN PROCESS explains the creative design and innovation process that was deployed in designing the reported mobile art applications. It lays out a creative practice for designing modern multimodal applications for rich human experience in the field of ubiquitous computing. Rather than following the format of a design manual for user interface creation, it describes the thinking that guides the design process, from a holistic design perspective. It also looks at the research methods used in data gathering and analysis.

5 RESULTS presents a synthesized overview of the key findings and observations that this research produced. It first highlights the novel technology and design methodology outcomes and then presents and discusses the concepts that emerged across all four mobile art

applications. At the end, it also looks at the societal implications of this research work.

6 CONCLUSIONS AND FUTURE WORK summarizes the outcomes of this dissertation and explains how this research can be taken further.

1.2 RESEARCH QUESTIONS

In a broad sense, the outcomes of this dissertation aim to generate understanding regarding questions such as these: What will the new uses of mobile and ubiquitous computing technologies be, and in what way will they influence future art making? Will we have interfaces that fit our human senses, bodily interactions and gestural communication better than current technologies do? Will these technologies help us to regain a lifestyle that is more art- and culture-inspired than the socio-techno-driven style that we find in many modern societies nowadays? Will mobile and ubiquitous technologies help the general consumer become an artist with a DIY approach to be more creative and inventive in daily life, taking our future societies in new directions?

To explore possible answers, this dissertation focuses on three core research questions. The first is how to design multimodal interfaces for creating and sharing artistic expressions? The second is how can we create engaging experiences using these interfaces? The third is what do personal mobile phones have to offer in the context of mobile interactive application and multimodal interface design? The exploration focuses on deploying prototype applications which were built with a creative design and innovation process and put into users' hands to extract relevant knowledge and understanding.

1.3 ORIGINAL ARTICLES

The five original articles of this dissertation report the four mobile art applications that were produced during the doctoral research. Each article was published in English in peer-reviewed conference proceedings or journals; all are printed in this dissertation in their entirety. The articles are listed below, in the order in which they were published.

ARTICLE 1: "MobiLenin: Combining a Multi-Track Music Video, Personal Mobile Phones and a Public Display into Multi-User Interactive Entertainment" (Scheible, J., and Ojala, T., In Proceedings of the 13th annual ACM International Conference on Multimedia, ACM Press (2005), 199–208). This paper received the award for best paper in the conference's art paper track.

ARTICLE 2: "Combining Web, Mobile Phones and Public Displays in Large-Scale: Manhattan Story Mashup" (Tuulos, V., Scheible, J., and Nyholm, H., In Proceedings of the Fifth International Conference on Pervasive Computing, Toronto, Canada (2007), 37–54).

ARTICLE 3: "Story Mashup: Design and Evaluation of Novel Interactive Storytelling Game for Mobile and Web Users" (Scheible, J., Tuulos, V., and Ojala, T., In Proceedings of the 6th International Conference on Mobile and Ubiquitous Multimedia, Oulu, Finland (2007), 139–148).

ARTICLE 4: "MobiToss: A novel gesture-based interface for creating and sharing mobile multimedia art on large public displays" (Scheible, J., Ojala, T., and Coulton, P., In Proceedings of the 16th ACM International Conference on Multimedia, ACM Press (2008), 957–960).

ARTICLE 5: "MobiSpray: Mobile phone as virtual spray can for painting BIG anytime, anywhere, on anything" (Scheible, J., and Ojala, T., In Leonardo, The Journal of the International Society of the Arts, Sciences and Technology, Vol. 42, No. 4, 332–341, 2009).

Article 1 is about mobile **multi-user interaction with a large public display**. It presents the MobiLenin application that couples multimedia art with a nonconventional distributed human-computer interface for multi-user interactive entertainment, in form of mobile collaborative group action. The research reported in this article studied the role of a personal mobile phone in stimulating engaging social experiences and explored the device's contribution to a multimodal system incorporating visual and auditory modalities among others. Designing the MobiLenin application initiated the **process**

of rapid prototyping with Python for S60 to build and test fully working interactive systems. This process became a core component for designing each prototype application reported in this dissertation. The results of this article and the design understanding gained served as a starting point for the **art- and technology-driven research approach** of this dissertation.

Article 2 introduces a real- and virtual- world context to the design realm of this research by **linking spaces with different modalities**. It brings in the **field of pervasive game design** by reporting the design and testing of the large-scale pervasive game called Manhattan Story Mashup (MSM). MSM melds the Web, camera phones and a large public display together into a real-time collaborative street art platform. The article explores the use of a mobile phone as an interaction device for participating in **real-time collaborative activities** like public performance that take place in the physical and virtual world (Times Square and Web). But the article also assesses what mixed-reality mobile-phone games have to offer in terms of **stimulating engaging social experiences**, a key issue studied throughout the dissertation. Further, MSM introduces the role of a **mobile phone in facilitating interaction with the physical environment**, as it uses its camera for sensing the urban environment.

Article 3 reports a study of the design rationale and evaluation of MSM, the application introduced in article 2. Article 3 explores the role of a mobile phone for triggering creativity, supporting real-time collaboration and fostering social interaction; it then discusses how to design for that role. The article serves to establish the **mobile phone as a capturing and sensing device suitable** to create user-generated content in the context of a large-scale pervasive game. This identifies a key role that a mobile phone can take in **multimodal interaction**.

Article 4 introduces **mobile gesture control**. It presents MobiToss, a novel application for creating and sharing mobile multimedia art via throwing and tilt gesture control. The article serves to establish the **mobile device as an artistic tool for making art in public space** and to explore the user experience of **tossing digital content onto a large screen**. This contributes to the knowledge and understanding of how to design engaging experiences that incorporate vi-

sual, tangible and also kinesthetic modalities in a fixed-installation setting.

Article 5 introduces ubiquitous ephemeral digital art to this research. It presents MobiSpray, which employs the mobile phone as virtual spray can to spray dabs of digital paint onto the physical environment via large-scale projections. MobiSpray moves the users' activity away from a fixed screen into the open public space, where anything anywhere can become a canvas for interaction. It elevates ubiquitous computing to a new level, because it is about interfacing with the physical environment through kinesthetic, tangible and visual modalities available via a single small mobile device—no visible computer, computer keyboard or computer monitor is needed anymore. The gesture-based control of the mobile phone provides a **natural pointing mechanism** for the virtual spray can. This article explores the role of the personal **mobile phone as a creative art tool** and a means for **interacting with the physical environment**, highlighting contributions to the notion of **empowering mobile art practice**.

1.4 EARLY INSPIRATIONS

The seed for this thesis was planted as I worked on earlier new-media art projects. As a musician and performing artist, I wanted to create an interactive technology system to offer the audience the opportunity to engage with my live stage show in a new way simply by interacting with the music and video on a large screen. In the first installation, the shouting and clapping of a crowd of people was used to change the tracks of a multi-track music video shown on a public display. The main character in the music video was my artist alter ego, "Lenin's Godson" (the source for the follow-up mobile art application's name, MobiLenin, that combines 'Mobile' and 'Lenin', as MobiLenin uses mobile phones rather than clapping to interact with the video).

While studying the literature in order to prepare for this project, I came across the concept of "co-experience", which provided the early inspiration for my theoretical investigations related to my artistic experimental project. The concept of co-experience was recently introduced by Battarbee (2004) to describe user experience

during social interaction. Co-experience is a particular approach within user-centered design and proposes experience prototyping. The idea is that experience prototyping should happen in the real social and physical context of the future users' lives. This allows observing how users lift up experiences for each other and how others interpret and respond to them. Inspired by Battarbee's approach, I developed a creative design and innovation process specifically for my own research purposes, one that has prototyping, iterative design and user testing at its center. This led me to design and test the series of applications that are discussed in this work.

2

Intellectual context

2 Intellectual context

2.1 UBIQUITOUS COMPUTING

2.1.1 URBAN COMPUTING

Urban computing is an emerging multidisciplinary research field that studies the interaction of the urban space, people, technology and information. It builds not just on computing and engineering sciences, but likewise on arts and design and other fields such as economics, media and political and social sciences. A subtopic of urban computing is the field of urban street art, in which emerging ubiquitous technologies are put to use creating new forms of digital art and discovering new ways of making art.

Urban computing research has grown out of, notably, longer-term interest in mobile computing and wireless communication. Whereas many research studies have looked at mobility as a problem to overcome (e.g., GPS navigation, file synchronization over wireless connection), an emerging generation of applications is viewing mobility as a way to create interactive experiences that rely on or exploit movement and space (Bassoli et al. 2007).

Urban computing studies the integration of computing technologies into everyday urban settings and lifestyles (Kindberg et al. 2007). Due to complex ownership relationships and legal ramifications, urban settings are challenging places for experimentation and deployment, as the installation and operation of an application or an art piece typically require permissions from many stakeholders. Thus it is no surprise that the inherent freedom of playful arenas, combined with intimate ubiquitous technologies such as video projection, has led to a new breed of guerrilla performances (Sheridan et al. 2004). This dissertation work explores multimodal approaches in this context and uses the wireless infrastructure and mobile equipment to realize projects while achieving independence of fixed installations and stakeholder problematic (figure 5).

Figure 5. Use of mobile equipment in public space

2.1.2 MULTIMODAL SYSTEMS AND INTERFACES

Selke and Dittler (2009) predict that future media forms will have multimodal characteristics and will be orientated to the abilities and situation of the user. Whether it is sensorial, gestural, visual, audible or tactile, the current fixed link between media and infrastructure will not be there anymore. Sommerer et al. (2008) argue that ubiquitous content creation is an emerging genre that uses everyday media as platform for creative content able to generate emotional and entertaining experiences. Multimodal systems allow content to be visually, tactilely or audibly generated, transformed, seamlessly transported and then offered in different forms for consumption and experiencing. The multimodal systems described in this research work consist of multiple input and output devices, multiple views

and multiple display surfaces. The content generated, transformed and transported is processed with interactive applications that have multimodal interfaces. Input interfaces comprise a mobile-phone keyboard (text input), computer keyboard (text input), mobile-phone camera (photo and video input) and mobile motion phone sensor (gesture input). Output interfaces are computer screen (visual, sound), large public display (visual, video), mobile-phone display (visual, sound, video) and large-scale projection (visual) (figure 6).

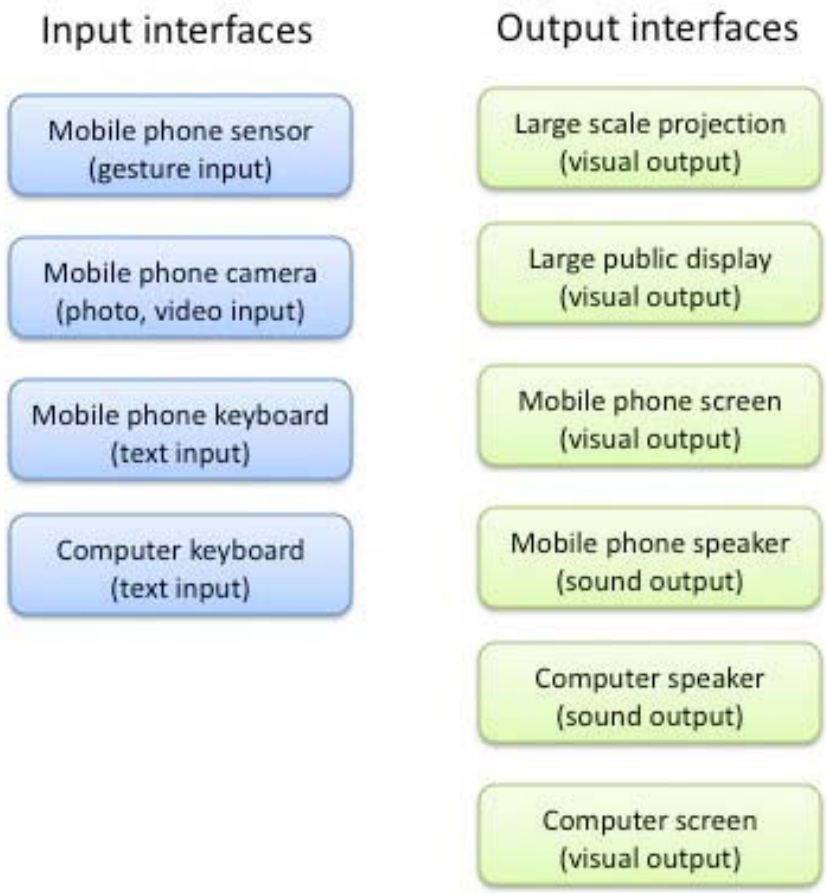


Figure 6. Input and output interfaces

The change to the form of content is central to this dissertation. Transformation from one medium into another, from physical to digital or from analog to digital and vice versa, is key to the design approach taken. Digital ubiquitous technology, in this case mobile, Internet and public display, build the framework to enable transformations to be performed. The mobile phone with its camera, processing power, memory, wireless connection and portability provides the affordances to make the transformations happen in the physical environment. This is essential when we seek to interact with the physical environment to create artifacts. This research work shows that the environment can be used as input source for creating digital artifacts or as an object to be transformed visually through projected light. It is the physical space that makes it highly interesting to explore the use of multimodal interfaces for art making.

2.1.3 FROM ANYWHERE ANYTIME, BY ANYONE, TOWARDS ONLY HERE ONLY NOW, BY US

When exploring how digital encounters can improve the experience of urban space, and how a system can improve the quality of social encounters, Schieck and colleagues (2006) argue that with the advent of pervasive technologies in public and urban spaces, we need to achieve a better understanding of the notion of place.

The notion of 'anywhere, anytime, by anyone' has been popular in numerous major research projects in the past, projects that have often concentrated on the 'e': the electronic, as in e-city, e-government, e-learning, e-business, etc. (IntelCities 2004). Typically, the Internet and mobile technologies have taken a leading role here. Nowadays, however, a new trend is visible focusing on the 'u'—the ubiquitous, as in the u-city, u-services, u-learning, etc. This trend indicates concentration ever more on the notion of 'only here, only now, and by us'. It reflects a shifting from space (movement space) to place (social place), or from globality to locality. Whereas the Internet and mobile technology in the past typically created a 'movement space', there are huge opportunities to use ubiquitous technology to create 'social place' (figure 7).

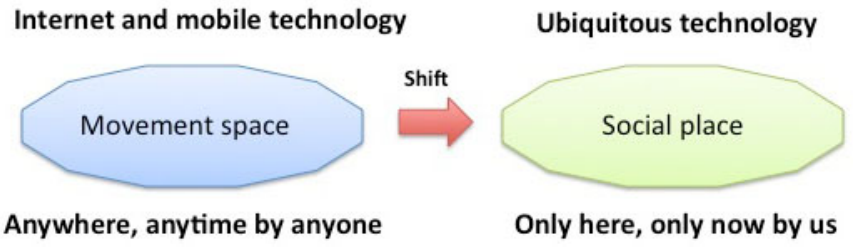


Figure 7. Shifting from movement space to social place

According to Carmona and colleagues (2003), places that are 'real' to people invite and reward involvement—intellectual and/or emotional—and provide a sense of connectedness. This dissertation research shows that by designing multimodal interfaces, we can create places that become 'real' to people, places that invite and reward involvement. This means we can build social places that provide new activities for being in a place. These social places will provide collective interactions in new ways based on social exchange. While there has been much discussion of the networked, virtual and online implications of the Internet, the social implications of such technologies in physical spaces have not yet been widely explored. Greenfield and Shepard (2007) have asked how our experience of the city and the choices we make in it are affected by mobile communications, pervasive media, ambient informatics and other "situated" technologies. This dissertation explores how creating and sharing engaging artistic activities through the use of multimodal systems can contribute to new experiences of the city and asks how multimodal systems can empower mobile art practice. Schieck et al. (2007) argue that designing new technologies within our physical environment is often accompanied by speculation about the technologies' potential to influence social behavior and shared encounters. This dissertation research shows how social behavior can be positively influenced by, and completely new mechanisms can be designed with, ubiquitous technologies, enriching human social experiences. However, not every system works as positively in every circumstance, since every setting is defined by a number of specific, decisive factors.

2.1.4 MOBILE COMPUTING

In recent years, mobile-phone features—wireless data rates, memory, processing power—have reached a level at which we can create completely new uses, activities and experiences with them, including some from the field of art. If we look at the major technological inventions of the last 15 years that have shaped our information society, we find all now being integrated into one device, the mobile phone: Internet access, GPS, messaging, e-mail, photo shooting, video recording, image and video viewing, music listening, sound recording, wireless LAN, motion sensors, Skyroscope and so on. Having all of these available on one device that fits in one's pocket, no less, provides a lot of freedom for creative, novel uses of this device. It allows us to turn the mobile phone into a sophisticated tool for art making, empowering mobile art practice.

2.2 ART AND SCIENCE OF INTERFACE AND INTERACTION DESIGN

Wakkary and Tanenbaum (2009) explain that adopting a conception of the user as a creative everyday designer generates a new set of design principles that promote sustainable interaction design. Bertelsen and colleagues (2004) argue that in future third-generation human-computer interaction, 'the cultural,' including digital art, will no longer be considered a stable backdrop for human-computer interaction, but will instead be understood to constitute the dynamics of human-computer interaction. These arguments are confirmed throughout this research, as all the applications designed are centered on the users' activity of creating digital art through human-computer interaction.

2.2.1 INTERFACE ECOLOGY

Interfaces are the medium of interaction (Kerne 2002). They constitute the situations in which representations are presented to and by the user and the developer, the subject and the object, the ethnographer and the other. Designing multimodal interfaces for interaction thus allows for the presentation of representations to and by the user,

through multiple modalities. However, while this opens new opportunities, it also provides new challenges in designing engaging interactive artifacts. Kerne (2002) argues that interactive artifacts are designed to engage people in accessing and developing knowledge and information. Their human-computer interfaces are instances of a broader set of phenomena; cultural, creative, technological and everyday frames of reference, spoken languages, economic positions, programming languages and run-time platforms converge through the lens of the interface nexus. When looking through that lens at multimodal interfaces, we discover the many possibilities multimodal interfaces offer for accessing such instances in deeper and wider scope (as compared to traditional interfaces) and specifically for designing for them. For example, this research shows that by designing multimodal interfaces, new art practices can be created for accessing cultural and creative instances, allowing people to engage in new types of social experiences and create cultural outcomes.

2.2.2 PUBLIC DISPLAY INTERACTION

In this work, public displays are essential to exploring multimodal interface designs for creating and sharing interactive experiences. Churchill et al. (2004) argue that there are significant opportunities around the corner for distribution of interactive multimedia digital content designed for social networking and entertainment. Rogers and Lindley (2004) state that there has been little research on how deploying public displays in different places invites certain kinds of social interactions. Instilling a sense of community is one motivation in situating large interactive displays in a variety of work and public places (Rogers and Lindley 2004; Churchill et al. 2002). According to Paek and colleagues (2004), interactive shared displays are most suited for certain types of applications, including "collaborative tools allowing multiple people to contribute to a single goal" and "arena applications involving competitive interaction". Almost all systems designed during this dissertation research incorporate collaboration and contribute to a single goal, instilling a sense of community by spurring social interaction among the users. Vogel and Balakrishnan (2004) asked what kind of input and interface technologies we must develop to allow for effective interaction with large public displays.

Many large display systems are currently single-user-based and require users to take turns when interacting with them. However, there is a growing body of work investigating the use of multi-user interactive displays (Brignull et al. 2004). The contribution of this research on interaction with public displays lies in showing that successful interaction models can be designed with multimodal interfaces, where mobile phones play a central role in interaction. Designing a hybrid interface allows combining the strengths and weaknesses of both public and mobile display. On one hand, there is the public display, with its strong conceptual power due to its large screen size yet also its frequent limiting of interaction to one user. On the other hand, there is the mobile phone, with its strength of dispersing control and access yet also its limited conceptual power due to its small screen size. Providing a private return channel from the large display system to the mobile phones in order to deliver confidential, user-specific content helps entice people to interact with a public display. This allows not only addressing individual users but also subgroups.

2.3 CREATIVITY AND USER EXPERIENCE

The major design goals for the prototypes built in this research included providing engaging experiences, triggering creativity and fostering collaboration and social interaction. By testing the prototypes in authentic environments, I hoped to gain understanding of how well the prototypes succeeded in reaching these design goals.

2.3.1 CO-EXPERIENCE: UNDERSTANDING USER EXPERIENCE IN INTERACTIVE SYSTEMS

In 2004 Battarbee (2004) introduced the concept of co-experience to describe user experience in social interaction. The term user experience has become popular in user-centered design in recent years, reflecting a holistic approach to understanding the relationship between user and product, as well as the experiences that result from their interaction. Co-experience as a particular approach within user-centered design promotes experience prototyping, which should happen in the real social and physical context of the future

users' lives. This allows observing how users lift up experiences for each other and how others interpret them and respond to them. Researchers can develop an empathic understanding of the experiences relevant to the users. At the same time, it is possible to study users' interaction with products and observe the emergence of meanings and purposes of technology.

2.3.2 CREATIVE PRACTICE AND EXPERIENCE

Nelson and Stolterman (2003) argue that, with our designs, we need to bring people from a traditional 'experience and adapt' feeling to an 'engage purposefully' feeling. By fostering creativity, the prototype designs of this dissertation work engage users purposefully. The 'flow' concept from Csikszentmihalyi (1990) presents a model for understanding how people become captivated by various kinds of experiences, from watching a movie to playing a video game to cooking a meal. Csikszentmihalyi's notion of flow describes these experiences as balances of skills and challenges. His model prescribes initiating participant involvement at a low skill and challenge level, then elevating both aspects equally through the life of the experience. Imbalances can cause anxiety (when challenges outpace skill) or boredom (when skill outpaces challenges). Discussing models of creative practice and experience and the potential application of these to new media arts and technology, Shamma and Shaw (2007) intentionally define the creative process broadly, encompassing everything from the actual construction of artifacts or experiences to the phenomenology of engagement with these artifacts or experiences and the understandings that arise from this engagement. Shamma and Shaw discuss two groups of models, the creator-centric and the experiencer-centric. The former focuses on construction of artifacts or experiences that seek to describe a space of possibilities for creators, to explore and to prescribe a method for undertaking that exploration. The latter focuses on the experience of the viewer as a piece of art reveals itself. Shamma and Shaw argue that new media is blurring distinctions between creator-centric and experiencer-centric models of creativity. There is need to seek out new models in which the 'user' of a creative work adopts a generative role, not just an interpretive or interactive one. This dissertation supports

this idea through its designs of engaging experiences. In Manhattan Story Mashup, for instance, the players—who are the 'users' of the interactive system—are the ones having the generative role, creating the artistic content by writing stories and shooting photos. They are thus the 'experiencer' and the creator of the art work. In all cases in this research, the designed creative practice delivered by the mobile art application leads to an engaging experience.

2.4 ART MAKING, GAMING AND CULTURAL PRODUCT CREATION

2.4.1 MAKING ART IN PUBLIC SPACE WITH MOBILE PHONES

While public space has for a long time been used as a medium for some art forms including sculpture and architecture, other art forms for public space were only recently established, for example land art and environmental art. During the 1990s, the field of new media came to life with the arrival of computers and software and led to new-media artworks, many in the form of interactive art installations and public interventions such as 'Augmented Trashcan' by Eric Paulos (Paulos and Jenkins 2005). In contrast, creating art with mobile phones in public spaces is an emerging form of artistic expression. Traditionally, mobile phones are used for many different things, although mainly for private communication in private and public spaces alike. People talk on their phones, send SMS, chat, e-mail, update social networking sites, take photographs or record video and share online. However, mobile multi-user games are a familiar example in which the mobile phone has been taken to the public space as playground.

From the earliest days of mobile phones' popularity, artists have been interested in using them for their own purposes. Pettit (2008) recycles mobile phones to create physical sculptures like 'Recycled Mobile Phone Art'. Paintings and drawings making statements about the impact of mobile phones on our society have emerged. For example, concrete sculptures of mobile phones by Will Coles (2008) have been placed throughout cities to be discovered and enjoyed by people, perhaps making them think about mobile phone use. In con-

trast, some artists use real phone functionalities to create interactive art performances in which audience members join. One inspiring example is 'Telesymphony', a project by artist Golan Levin (2001) that uses ring tones to make symphonies collaboratively. Another is 'Mark Shepard's Tactical Sound Garden' (Shepard 2007), which draws on the culture of urban community gardening to posit a participatory environment for new spatial practices and social interactions within technologically mediated environments.

2.4.2 PERVASIVE GAMING

Pervasive gaming has been one of the more prominent research areas in the field of ubiquitous computing. A pervasive game is a game that is part of the daily life of the player. Pervasive gaming is a new form of multimedia entertainment that extends the traditional computer-gaming experience out into the real world. Through a combination of personal devices, positioning systems and other multimedia sensors, combined with wireless networking, a pervasive game can respond to a player's movements and context and enable them to communicate with a game server and other players (Capra et al. 2005). For example, in 'Uncle Roy All Around You', a console game breaks out onto the streets (Benford et al. 2006 b), involving players both in the field and in a parallel virtual world; street players are tasked to search for a character named Uncle Roy. In 'Can You See Me Now' (Benford et al. 2006 a), online players are chased through a virtual model by street players who play in a real urban environment. In this dissertation research, pervasive gaming is used as a framework to test the deployment of a mobile interactive system combining the Web, mobile phones and public displays across multiple spaces, with Manhattan Story Mashup being the prime example.

2.4.3 CREATING CULTURAL PRODUCTS

The prototype designs described in this dissertation enable users to produce content in the form of creative and artistic output that can be seen as cultural products. A rich variety of groups of people can thus become creators and receivers of such cultural products. The validated designs aim to inform future design and implementation

of ubiquitous media production applications and to discuss methods and practices of future real-time generation, such as new forms of cultural products.

2.5 ARTIST-ENGINEER ETHOS: ARTISTIC MOTIVATION AND INNOVATION

A supplementary goal of this dissertation is to prove that artistic creativity can be combined with innovation—they often are, especially in the academic side of the arts field—despite the combination often being perceived as something of a mismatch (Academy of Finland 2009). In a practical way, this work illustrates how research can be related to artistic practice, in terms of reflection and systematic development of theory and explanation of creative practice: how art, technology and design enable innovation and a body of knowledge.

This dissertation shows how my research conceptualizes a metadisciplinary ecosystems approach. The different disciplines were not attached through different persons, as is typically the case in research projects, but instead by uniting the skills of several disciplines in one person, myself, an artist and engineer. While this constellation has some weaknesses, in my opinion it is highly fruitful when working in the field of ubiquitous computing and new media, where a creative outreach is needed. Being educated as an artist and engineer allows me to take a holistic approach, to shape a project from the beginning to the end, from the artistic inception to the engineered system. This approach is required more strongly than ever as the field of ubiquitous computing needs to enter domains of a social and cultural nature. Developing purely engineering solutions cannot live up to the needs such systems must fulfill. For this reason, in the new-media education of the future, teaching multiple disciplines should continually be taken into account. It would even be useful to expand engineering studies to some extent towards media art studies, as this field can be highly motivational and inspiring for engineering professionals, too.

With the artist-engineer identity, the mindset lets you come up with creative and novel concepts from the perspective of art-inspired practice and experience. The mindset also lets you guide the tech-

nical implementation process, including the system design, from a holistic perspective. You can shape it according to your own imagination and intuition. Understanding both sides, the art and design as well as the technology, helps you also to communicate with people from other fields, in order to achieve the desired outcome: you are familiar with the same terminology and can grasp each other's way of thinking. Whether it is the desire for artistic expression, designing engaging activities or developing technically complex systems, you yourself can take it to a level where you can communicate and share with people from other disciplines and get them involved.

3

Design process

3 Design process

This chapter describes the creative design and innovation process that was deployed in designing the mobile art applications reported in this dissertation. The adopted approach lays out a creative practice for designing multimodal applications for rich human experience. Rather than following the format of a design manual for user interface creation, the chapter describes the way of thinking that guides the design process, from a holistic design perspective. The last section of the chapter looks at the research methods used to validate the created mobile art application designs and explains how data was gathered.

3.1 PROCESS DESCRIPTION

3.1.1 OVERVIEW OF THE CREATIVE DESIGN AND INNOVATION PROCESS

The deployed design process is a form of user-centered design. In particular, it relates to user-centered design through the characteristics of the active participation of real users in the design process. The closest related design theory is that of co-experience, developed by Battarbee (2004), described in the first chapter. Co-experience is a particular approach within user-centered design and promotes **experience prototyping**. The novelty of the creative design and innovation process described in this dissertation lies in proposing a rapid prototyping approach using Python for S60, or PyS60 (Scheible and Tuulos 2007) in combination with a 'creative mobile toolkit' (Scheible 2006) I developed to **extend experience prototyping**. In concrete ways, this constructs a **practical means for realizing experience prototyping fast**, especially in the field of ubiquitous computing and multimodal interface deployment. This allows quick placement of fully functional prototype applications into the hands of users and makes it possible to study experiences that are relevant to users. In this work, 'prototype' is defined as a working solution with full functionality that is ready to deploy in the field for testing in its entire scope; it is by no means a solution to be seen as a market-

ready finished product, nor should it be viewed as having undergone any reliability testing for long-term usage.

PyS60 plays a central role in the design process, as all mobile client applications reported in this dissertation were programmed with it. The discussion on PyS60 in this chapter views its characteristics from a design perspective. Technical qualities are discussed in chapter 4.

The applied design process is illustrated in figure 8. It consists of three major phases: 'Informing design goals', 'Rapid prototyping with PyS60' and 'Analysis';'Analysis' is embedded within the 'Rapid prototyping with PyS60' phase.

The design goals here are informed by a variety of considerations at the start of the process. Initially, these design goals form the 'incremental design' that builds up within the 'Rapid Prototyping with PyS60' phase. Art practice and technology are in a dynamic state within the iterative cycle, as they inform each other through user-testing results. The embedded analysis phase leads to understanding of user experience and generates potential innovation. Analysis feeds back into the cycle as well as into the early design goals.

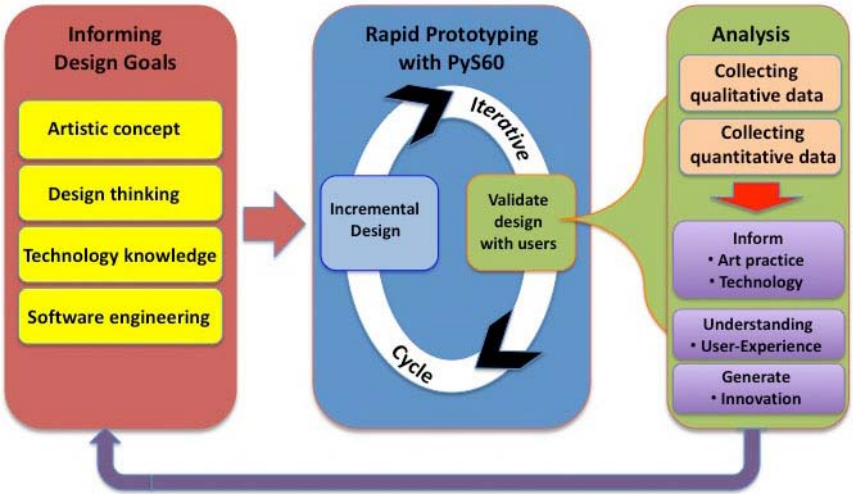


Figure 8. Overview of the creative design and innovation process

3.1.2 INFORMING THE DESIGN GOALS

ARTISTIC CONCEPT

My approach has been art-inspired rather than technology-driven. Instead of asking what I could do with a particular technology, I aimed at creating a concept inspired by artistic practice. I wanted to design my projects from a holistic point of view poised to give users new, enriching and social experiences—something to allow them to express themselves artistically or use their creativity while also being entertained. For me this means to bring 'life and sensuousness into the realm of the digital,' as compared to staying on the proverbial 'cold' and 'abstract' levels that have become almost synonymous for 'technical' in the field of ubiquitous computing. Once this 'life and sensuousness' concept is shaped, it is time to think about the technologies that would be needed to realize the concept. This has led to solutions based on multimodal systems, in which mobility and the mobile device take central roles.

DESIGN THINKING

The following ideas drawn from Nelson and Stolterman's work (2003) inspired my thinking in many ways as I designed my prototypes. I have interpreted and tailored their thinking to fit my specific needs.

'Create beauty and evoke the sublime; Experience of the sublime— an experience that moves us and transcends senses, feelings and emotions'. This goes well with my desire and vision to bring 'life and sensuousness into the realm of the digital'. The users that live an experience by using my mobile art applications should achieve, even if on a remote level only, an experience that 'moves' them and 'transcends their senses, feelings and emotions'.

'Design is not just about creating something new. It is about a whole, by adding something new to something already in existence.' The creation of a whole is something I kept in mind when taking a holistic approach to my system designs and interfaces. This emphasis on the whole comes across clearly in viewing the piece 'Trash to Treasure', which was created with MobiSpray (figure 9). The projected colors and shapes are added as something new to something—

Figure 10. The city as playground

the trash—that was already in existence, forming the new whole, the treasure.

'We need to attempt to grasp the conditions and context that exist. This will set the stage for our ideas and new design.' Being aware of conditions and context has helped me to avoid trying to re-invent the wheel in my designs. Instead, I closely analyze the situations and surroundings where I want to place my new concepts. The Manhattan Story Mashup application, for example, was designed in light of an existing city's conditions and context. The city served as a playground and place to find objects to photograph (figure 10).

'Seeing the not-yet-existing'. This is the most essential thought influencing my design process. Stolterman and Nelson (Nelson and Stolterman 2003) use it to argue that design is an act of anticipatory image formation. They view design as an act of imagining the future, the not-yet-existing. They explain that designers are often demanded to conceptualize their ideas in a way that make them communicable and comprehensible to everybody involved in a design process. A designer's formative powers are therefore needed both to come up with the unexpected idea and to 'give form' to that idea so that it can be communicated. They refer to the philosopher Immanuel Kant, who reasoned that the ability to 'give form' to an idea could be described as the designer's FORMATIVE FACULTY (Nelson and Stolterman 2003). For Kant, the imaginative formation does not have

its cause in the real representation. It arises instead from an activity of the soul. That term, soul, might not appear frequently in design research literature, but according to English dictionaries it can denote emotional or intellectual energy or intensity, especially of the kind revealed in an artistic work or performance. Synonyms for soul include life force and vital force. This goes well with my idea of 'bringing life to the digital'.

Rapid prototyping reveals something that relates to the notion of 'seeing the not-yet-existing' and 'giving form' to an idea. While in this case, the prototyping process helps to produce real representations of the artistic concept, it also has a side effect of 'aiding your formative powers', as I would call it. The process of rapid prototyping puts the designer in a position where imagination and creativity are let go to trigger new, unexpected ideas when the prototype is put into the hands of people. Looking at how people use your design, you may start thinking what else people could do with it, what other features could be derived from the revealed behavior and how your design might be improved to extend user experiences. This aids your formative process, helping you to 'give form' to your ideas. Especially by reviewing video interviews with test users who used your prototypes, you are struck by new ideas regarding your design, since interviewees often speak their opinions freely and from their own angles, their minds freshly influenced by their experiences.

You gain understanding of the experiences that are relevant to the users, as a discussion of co-experience would describe it (Battarbee 2004). By looking at what users say and then by looking beyond your current design, you start 'seeing the not-yet-existing', and you have the ability to 'give form' to an idea. The fast iterative design cycle of rapid prototyping allows you then to develop your design in many directions, leading to a multitude of new ideas for the future, helping you to create innovation.

TECHNOLOGY KNOWLEDGE

Thanks to recent developments in information and communications technology (ICT), many of the artistically motivated concepts in this dissertation were realizable. Concepts such as client-server mechanisms, wireless communication and sensor technologies are essential to my works, as are the rich set of contemporary mobile-phone

features, including camera, sound, graphics and wireless Internet access. Only a few years ago, it would have been impossible to realize these ideas. Certainly, my background and experience as an engineer helped me to feed the technical knowledge into the design process, particularly by understanding how to map artistically motivated features to technically feasible solutions. Many times, the major design decisions were made on technical grounds, such as nonfeasibility or calculating that the technical implementation would require too many resources. Sometimes, my decision was to cut down on features and rethink the artistic concept, in order to achieve a working prototype. Technological knowledge helped also in those projects for which I did not build the technology myself, such as the MSM. In this case, it was essential that I be able to play the role of mediator to redirect the artistic design.

SOFTWARE ENGINEERING

Being a programmer allowed me to design the software for most of the mobile art applications, in DIY manner. During the iterative design stages, this was highly useful in making design adjustments based on findings from prototype testing in the true environment of use. Knowing what feature on a phone can be implemented in what way helped me tremendously in shaping the development of the prototypes. For example, I often needed to know what kind of new functionality outcome could be achieved if several features were combined. I developed MobiLenin, MobiToss and MobiSpray—on my own— in a matter of days and weeks, not months or years. Lengthy, inefficient development periods are common in comparable multidisciplinary projects in which several people from different backgrounds work together.

3.1.3 RAPID PROTOTYPING WITH PYS60

RAPID PROTOTYPING

Rapid prototyping has a relatively long history and is a broad field encompassing many domains and varied approaches. It has been used in manufacturing industries for fast physical fabrication of a design or concept, for purposes such as demonstration or evaluation. It has also been used in software engineering for testing techni-

cal feasibility. In the field of HCI and ubiquitous computing, rapid prototyping has become widespread. Fitton et al. (2005) used rapid prototyping and user-centered design of interactive display–based systems, while Ballagas (2003) deployed rapid prototyping to create new mobile-phone interfaces for ubiquitous computing. In many cases, rapid prototyping is used for making proof of concept. According to Nielsen (1993), the idea behind prototyping is to save time and costs to develop something that can be tested with real users. These savings can only be achieved by somehow reducing the prototype compared with the full system. In recent years, however, technology and software toolkits have drastically advanced and now offer rapid development of a system plus the advantage of nearly full functionality achievable in a short period of time at low cost. In this category falls Python for S60, when combined with a 'creative mobile toolkit' (Scheible 2006) that I developed myself. Both are at the heart of the design process described in this dissertation. Other toolkits fall into similar categories. For example, d.tools (Hartmann et al. 2006) and iStuff (Ballagas et al. 2003) provide a set of software tools in addition to hardware components to support the full range of design, testing and analysis activities in an iterative design cycle. Both iStuff and d.tools provide an extensible software and hardware framework that allows multiple platforms to be combined during prototyping activities.

THE ROLE OF PYS60 IN THE RAPID PROTOTYPING PROCESS

Runs on off-the-shelf mobile devices. In contrast to the toolkits mentioned above, PyS60 is a 'software only' toolkit that runs on common off-the-shelf mobile devices (S60 platform only) (S60 2008). PyS60 does not require any additional hardware, as many of the other toolkits do.

Large number of phone features available. PyS60 offers a huge number of phone features that can be quickly programmed. It was thus highly suitable for the design process of this research, with its fast iterative cycle. The advantage was significant compared to prototyping toolkits based on a sandbox model that often have a limited amount of phone features available or are time-consuming to program. PyS60 enables the designer to create complex but fully work-

ing mobile-phone applications ready for testing with the real mobile device, which allows:

- gaining understanding of the experiences relevant to the users
- informing of art practices and technology
- seeing of 'the-not-yet-existing' and fostering of innovation

Reusable code snippets. Being able to continually and quickly adapt the design of an application during an iterative design cycle within one's prototyping process is key. This can be achieved with PyS60 by using combinations of reusable code snippets that can be quickly modified. A large number of reusable code snippets have been developed during this research. Step by step, I bundled these code snippets into a 'creative mobile toolkit' that was used in building all prototype applications for this dissertation. I put the code snippets online (http://www.mobilenin.com/pys60/menu.htm) in the first place, to create easily accessible storage space. Then I turned the page into a tutorial available to people around the globe to learn how to program a mobile phone in DIY style. Further, I created a one-week workshop around the topic of rapid prototyping on the mobile platform, which I have gone on to teach at many conferences and universities worldwide, including MIT, Stanford, CMU and NTU Taiwan. For this workshop, I used the code snippets and the knowledge gained from my research to help students implement their own ideas on their mobile devices. The nature and diversity of the outcomes demonstrated the power PyS60 offers when combined with my toolkit as a prototyping tool. This led to refinements of the entire tutorial and toolkit. Eventually, the book 'Mobile Python' (Scheible and Tuulos 2007) evolved, cowritten by myself and Ville Tuulos. 'Mobile Python' has become a useful handbook for many mobile enthusiasts. It assists artists and designers in quickly focusing on ideas and concepts rather than spending weeks or months on programming alone.

With PyS60 and the 'creative mobile toolkit', it seems the possibilities for applications to build are endless and up to the designers' imaginations and creativity. Simply by making quick code modifications, a fast iterative design cycle is possible, and many different designs can be tried out. This fosters innovation and produces applications and products that fulfill people's needs. Again, it empowers mobile art practice.

3.1.4 ITERATIVE DESIGN

Iterative design refers to a design methodology based on a cyclic process of specifying, prototyping, testing, analyzing and refining a work in progress. In iterative design, interaction with the designed system is used as a form of research for informing and evolving a project, as successive versions. The new versions of a design should get progressively better as its designers learn what works and what does not, in a process of refinement and continual improvement. The motivation for iterative design is that very rarely is the first design a complete success. This is very much true for the design of a city or an urban space, which can be regarded as the most advanced instance of information technology.

The design process used in this research features 'iterative design' at the heart of its 'rapid prototyping with PyS60' approach (figure 8). In the course of numerous iterative cycles, new features are added step by step until the design reaches the desired form. An important part of these design cycles is the validation of the prototype application in authentic environments with real users, to gain understanding of the experiences that are relevant to the users. This allows users to react to the design and suggest changes. When this is done early on in the design phase, it generates findings about needed changes that inform the next design stage. Does the design fulfill real needs of people, whether the need for fun, entertainment, social interaction, face-to-face encounters, whatever? The iterative design cycle helps in making good design decisions early on. For example, you can identify very quickly what works for people and what does not, and you can see in which direction you need to develop your design so that it can provide the desired user experiences.

3.1.5 VALIDATING PROTOTYPE DESIGNS WITH USERS

To complete the testing and evaluation of the prototyped applications in authentic environments of use, the prototype applications were tested in specific locations that fitted the real location the systems were designed for.

The **MobiLenin** application was tested in a local restaurant, where 14 test users (8 males and 6 females) participated in an experiment.

For the most part these users were recruited on the spot, but some were recruited in advance through a university e-mail roster.

The **Manhattan Story Mashup (MSM)** application was designed for play in New York City, around Times Square; research data was collected from the actual game event. In total, 184 players played the game, of which 140 were recruited university students. The remaining players were persons from various companies and institutions. Feedback was collected from 99 players directly after the game.

The evaluation of **MobiToss** with real users was carried out at a social event that was part of an international conference. In all, 25 people tested the system and gave feedback. Most were researchers specializing in mobile multimedia.

MobiSpray has been tested for data-gathering purposes at three different sessions. Altogether 17 people (age 13–70 years) used the application and sprayed. These users were either passers-by over several days in a city square featuring a fixed installation of MobiSpray; or they were visitors at a large evening party where a MobiSpray indoor setup served as entertainment; or they were new-media enthusiasts at an ad hoc guerrilla spraying occasion in downtown Vancouver, Canada.

3.2 DATA AND METHODS

3.2.1 DATA GATHERING

Research data was collected during the validation session using a variety of methods.

QUALITATIVE DATA rreflecting the user experience was collected with:

- **Questionnaires** comprising open-ended questions, which test users filled in after the experiment.
- **Video interviews** of individual users and groups of users, carried out during the experiment and directly after it.
- **Observation** using video camera to shoot a panorama of the whole experiment

QUANTITATIVE DATA was collected through:

- **Server logging** for the purpose of computing statistics.
- **Questionnaires** with statements to which users responded using a 5-point scale, 1 indicating 'disagree completely' and 5 indicating 'agree completely'.

VIDEO INTERVIEWS

The video interviews were found to be highly useful and informative,, because they allowed the test-users to speak from their own perspectives with their own words and methods of expression. The following types of interviewing methods were used.

IN-SITU INTERVIEWS

In a number of cases, I chose in-situ interviews as my method, going round with my video camera to the test-users during the prototype validation session. This useful method was typical of in-situ interviews, asking on-the-fly questions arising during actual situations. To get data for evaluating MSM, I went along the streets of Manhattan and interviewed players as they searched for objects to photograph, and I also stood in front of the Reuters display to interview players arriving to see their story results on the large display. When testing MobiSpray, I interviewed test users at Federation Square directly in front of the large screen, asking them questions while they were spraying. In the ad hoc guerrilla session in Vancouver, I interviewed the sprayers in the darkness while they put their paintings to the walls. Each time I approached a test-user for an interview, I asked before it began if they felt comfortable about being recorded during their interview

SEMI-STRUCTURED INTERVIEWS

When conducting the video interviews for testing the MobiLenin application, I used the semi-structured interview method. It is flexible, allowing new questions to be framed during the interview as a result of what an interviewee says. I had prepared in advance a framework of topics to explore with each group of test users, in order to ask them a consistent basic set of questions. Similarly, for testing MobiToss I went round and interviewed test users after they had gone through the 'throwing' experience. Even though the ready set

of questions helped us stay on track during interviews, the most interesting answers were those to questions I asked to follow up a test user's previous response. I used this method to seek contextual understanding of an individual's social experience in depth.

OBSERVATION

When validating the MobiLenin application, observation was carried out during the experiment with three video cameras. One fixed camera shot a panorama of the whole experiment, while another fixed camera recorded the public display and a mobile camera shot close-up footage of users. A digital camera was also employed for taking still photos. Test users were informed about the observation before the experiment.

BALANCING SURVEY QUESTIONS

When preparing questionnaires, finding the right balance in the design of the survey questions in order to avoid bias can be tricky (Fowler 1995). The risk of inadvertently phrasing questions positively or negatively in a way that makes them leading must be avoided, for example. This is one problem I encountered when evaluating both MobiLenin and Manhattan Story Mashup. In hindsight, the questionnaires should have been improved and pre-tested before being distributed, in order to secure balance and minimize possible bias. Nevertheless, in both cases, in combination with the results from the video interviews the survey data gave useful insights to validate the design and to understand the user experience of participants

3.2.2 DATA ANALYSIS

The questionnaire for the MobiLenin evaluation contained 21 statements that users were asked to respond to using a 5-point scale ranging from 1 (disagree completely) to 5 (agree completely), plus 13 open-ended questions. In total, 11 filled-in questionnaires were available for analysis. In the Manhattan Story Mashup evaluation, the questionnaire contained 26 statements answered with the same scale; in addition, there were 23 open-ended questions. A total of 99 filled-in questionnaires were available for analysis. In the MobiToss

and MobiSpray evaluations, only video interviews were available for analysis, as no questionnaire was handed out.

ANALYZING VIDEO INTERVIEWS

All videos were viewed multiple times, and notes about valuable information were made in order ultimately to evaluate the content using interpretive techniques. A number of the video interviews were transcribed, not only so that content could be analyzed but so that test-users' phrases could be included in the research publications.

ANALYZING SERVER LOGS AND QUESTIONNAIRES

For analyzing quantitative data such as server logs and some portions of questionnaires, statistical analysis methods were used.

ANALYZING QUESTIONNAIRES WITH OPEN-ENDED QUESTIONS

For analyzing the qualitative data, interpretive techniques were used with which the data was examined and interpreted and impressions formed that could be rendered in a structured format. To see detailed information of the gained understanding and statistical analysis results of each of the evaluated applications, see the individual articles.

4

Technology

4 Technology

4.1 RELEVANT TECHNOLOGY COMPONENTS OF MOBILE INTERACTIVE SYSTEMS

The following paragraphs describe the major technology concepts that were relevant for building the mobile art applications developed in this study

4.1.1 CLIENT-SERVER ARCHITECTURE

All projects described in this work were realized with a client-server architecture. It comprises two main components: a Symbian client application running on a mobile phone and a server running on a PC. The client-server architecture allows for a dedicated server that can handle tens or hundreds of users simultaneously. Each client application on the phone was designed and implemented with PyS60. The server consisted of the Apache web server software on the one hand, to handle basic server functionalities running on a PC; and on the other hand, the PC, which also hosted further software applications that were part of the interactive systems. These software applications were implemented with software tools such as Adobe Director (Adobe Director 2009) in MobiLenin; MAX/MSP Jitter (MAX/MSP Jitter 2005) in MobiToss; Pygame (Pygame 2007) in Mobispray; and as a tailored program made with Python (Python 2009) in Manhattan Story Mashup. Deciding which software tool to use for implementing the main application on the server side was often a design choice influenced by how easy it was to realize a prototype with the envisioned functionalities, and by looking at the technical options it offered. In some cases—for Manhattan Story Mashup and MobiLenin—the servers resided physically at some service provider's location; in others—for MobiToss and Mobispray—servers were simply part of a portable laptop solution.

4.1.2 PERSONAL MOBILE PHONE

An increasing number of today's personal mobile phones are so-called 'smartphones'. The following list shows the most important functionalities of current smartphones useful in designing mobile interactive applications. The key is to combine these functionalities in new ways in order to invent novel applications for new uses.

- Bluetooth (RFCOMM, OBEX)
- Camera, taking photos, recording video
- Location, cell ID, GPS data
- Networking, HTTP, HTTPS, FTP, TCP/IP, UDP
- Graphics,photo images, animations
- 3D graphics, OpenGL ES
- UI elements, pop-up notes, menus, selection lists
- Sound, play and record sound, Midi files
- Motion sensor, read XYZ data in real time
- Compass
- Video player
- Text-to-speech engine
- RFID reader
- Messaging, send SMS and MMS
- Wireless communication, 3G/GPRS/HSPA, WLAN
- Color display
- Keyboard keys

All of these features are often accessible through software and can be used from within a single script or program. This enables giving the mobile phone a rich variety of roles, as this dissertation shows (see chapter 7, 'Results'). It makes the mobile phone highly attractive for prototyping, since one can create fully working, full-featured applications on the phone. Processing power and memory scarcely put up any limits anymore, as compared to just a few years back. Scripting languages such as Python and the PyS60 toolkit have eased mobile application development and have thrown open for mobile artists and interaction designers the door to the world of programmable mobile phones (Scheible and Tuulos 2007).

4.1.3 WIRELESS COMMUNICATION

Wireless communication is a crucial aspect of mobile interactive systems. It allows multi-user participation in real time, independent of distance: for example, interacting with a public display in MobiLenin and MobiToss. It also liberates the artist to move freely around an object while painting, as with MobiSpray. Further, it provides the opportunity to move through physical space while playing a game, as in Manhattan Story Mashup. As wireless communication technologies are WLAN and Bluetooth ad hoc networks, as well as GPRS, 3G or HSPA available.

WLAN AND BLUETOOTH AD HOC NETWORKS

The WLAN and Bluetooth ad hoc networks were found to be highly useful for building mobile interactive systems, as they can be used for various communication modes, such as a) phone-to-phone, b) phone-to-computer or c) phone-to-Internet. Let's look at these in detail:

a) Phone-to-phone communication

A connection is established between two phones (figure 11). In the case of Bluetooth, the standard built-in Bluetooth functionality of a phone can be used and offers the RFCOMM protocol (RFCOMM 2009) for serial communication. One phone runs a server script (server) and the other runs a client script (client). The maximum dis-

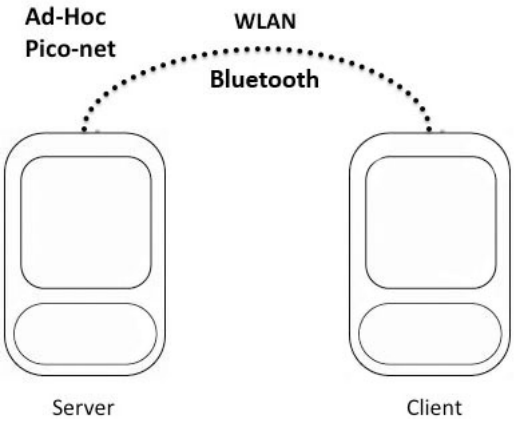


Figure 11. Phone-to-phone communication

tance is typically 10m between the two devices. Most modern smartphones have built-in WLAN functionality that can be used instead of Bluetooth and offers a greater distance and higher bandwidth.

Mobile webserver. For Nokia S60 phones there exists a Mobile Webserver software package (Mobile webserver 2008). It offers functionalities similar to an Internet webserver, including HTTP handling and so forth. With PyS60, one can create applications that communicate, then, from phone to webserver on another phone over both— Bluetooth and WLAN. This setup allows the designing of mass, participatory, real-time interactive activities enabling creativity in a whole new way: independent of location and space.

b) Phone-to-computer communication

Similar to phone-to-phone connection, Bluetooth (Figure 12) is also an option here, simply by running a client script (programmed in PyS60, for example) on the phone that communicates via the RFCOMM protocol (RFCOMM 2009) with the computer that nowadays often has a default built-in Bluetooth module. On the computer, a program must be run that handles the RFCOMM communication. Software packages such as Max/MSP (MAX/MSP Jitter 2005) and Processing (Reas and Fry 2007) have their own modules available that do exactly this. Additionally, the OBEX protocol can be used for phone-to-computer connection (OBEX protocol 2009); in such a case,sending entire files in both directions is possible.

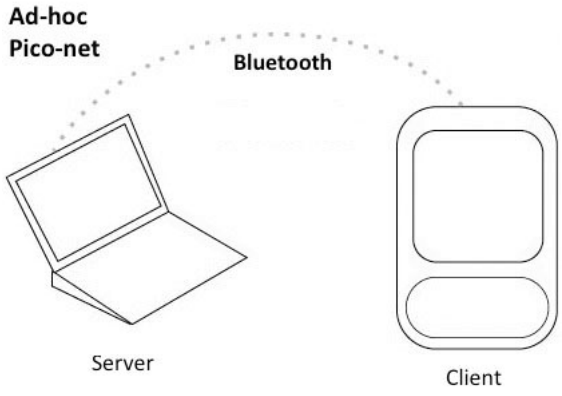


Figure 12. Phone-to-computer communication: Bluetooth

When it comes to utilizing WLAN for phone-to-computer connection, there are several setups possible, for example:

i) Creating a WLAN access point on the computer (figure 13).
ii) Connecting to an nearby WLAN network with existing WLAN access point (figure 14).

Some computers, including Apple's MAC, have built-in WLAN functionality, which allows for creating a WLAN access point on the computer, option i above. This setup provides an IP address of its own. A webserver running on the computer handles all standard communication protocols, such as TCP/IP or UDP port communication and HTTP, etc. Other WLAN-enabled devices can connect, then, to this computer. This setup is a highly portable solution, which is needed for applications such as MobiSpray, because the user needs only a phone and a laptop to run the entire mobile interactive application.

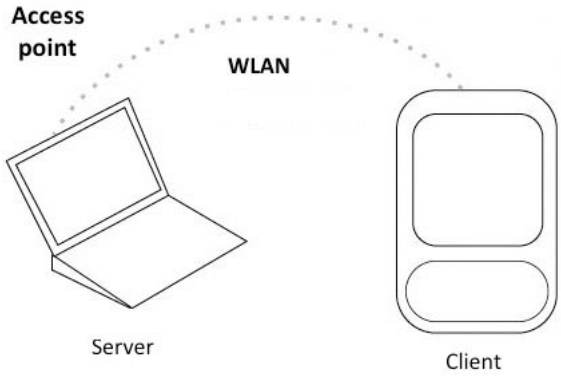


Figure 13. Phone-to-computer communication: WLAN AP created on computer

When connecting to a nearby WLAN network with existing WLAN access point (setup ii) to communicate between the phone and the computer, the PC receives its IP-address from the nearby access point. The phone can then connect to that IP address through the same nearby WLAN access point or some other access point (figure 14).

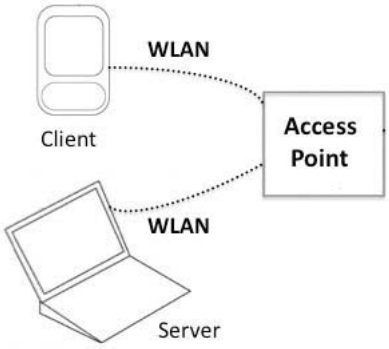


Figure 14. Phone-to-computer communication: Using nearby WLAN access point

c) Phone-to-Internet communication

In contrast to both phone-to-phone and phone-to-computer communication, which often involve a local portable PC component at their core, the phone-to-Internet connection (figure 15) is useful in cases in which the main user application of the mobile interactive system runs distributed on one or several webservers, whose locations are unimportant (meaning they reside anywhere on the Internet). The big advantages here are scalability and robustness, as hundreds or thousands of users can connect at the same time from any location, with no bottleneck in data throughput.

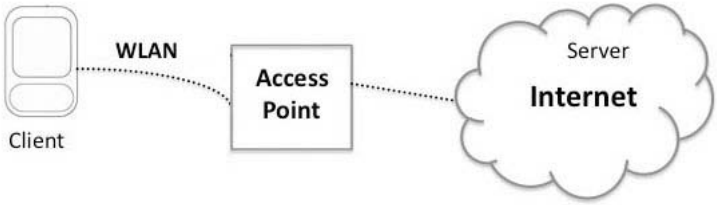


Figure 15. Phone-to-Internet communication

3G, GPRS:MOBILE DATA NETWORKS

GPRS, 3G and HSPA are the typical wireless technologies (Wireless technologies 2009) connecting mobile phones to the mobile-phone networks and mobile data networks. When designing mobile interactive applications for users who are distributed over large distances and at various locations, these wireless connections are, obviously,

highly useful. They allow data to be transferred quickly, while maintaining very strong network coverage in most countries. In contrast to WLAN and Bluetooth technologies, however, GPRS, 3G and HSPA involve significant cost, in that SIM cards need to be purchased from mobile network providers to access their networks. For the projects covered in this dissertation, we deployed GPRS and 3G, as well. This was necessary for Manhattan Story Mashup, whose players needed to be online continuously while they freely roamed downtown Manhattan. In the MobiLenin project, we also used GPRS and 3G, even though every participant was sitting in the same room. The simple reason for this was that smartphones did not yet have WLAN functionality built-in, in the days when the projected was realized.

4.1.4 GESTURE CONTROL

Gesture control has become popular in recent years, especially among computer game fans with the arrival of the Nintendo Wii game console (Nintendo wii remote 2008). Its Wii controller contains a built-in accelerometer sensor to allow controlling computer games with motions and gestures in real time. Many of today's off-the-shelf mobile phones are also equipped with built-in motion sensors. Though their original implementation purpose was mainly to switch the mobile phone screen between portrait and landscape mode, motion sensors are nowadays used for many other things, such as steering a car or moving a mouse on the computer screen. A sensor API in the software of mobile phones often allows access to the motion sensor's data. It can be read out with a high frequency. For example, values of the 3-dimensional axis XYZ are available, meaning they can be mapped and used for creating gesture control in real time. The values can either be sent to a computer to control software-parameters, or they can simply be used directly inside an application that runs on the phone. MobiToss and MobiSpray both utilize the built-in motion sensor of a mobile phone in order to perform gesture control. In MobiToss, the user can 'throw' a photo or video clip onto a large public display for instant viewing. The user can then manipulate the video on the public display by tilting the phone in different directions. In MobiSpray, the gesture control provides a natural pointing mechanism for the virtual spray can as users perform freehand painting.

4.1.5 PUBLIC DISPLAYS AND VIDEO PROJECTION

Public displays have become more and more common in larger cities in Europe and Asia. Often, they are deployed for digital signage, but also as systems allowing browsing of information such as bus schedules or watching location-dependent photos or videos via an interactive touch screen. A series of such interactive displays have recently been installed in the city of Oulu in Finland as part of a research project called the UBI (UrBan Interactions) program (see figure 16). Each display consists of a built-in PC that handles the dynamically changing content and information on demand. Tailored middleware controls and manages a cluster of displays and permits users to interact not only by touch screen but also via their mobile phones,. for example to play participatory games or to download content.

Figure 16. Interactive Public display installation in Oulu, Finland

Large public displays such as the cluster of networked screens deployed by the BBC in a number of cities in the UK (BBC Manchester, Public screens 2007), or the large screen at Melbourne's Federation Square (Federation Square 2002) serve the purpose of entertainment and information sharing as well as education. These screens are typically made of LED display modules or tiles and achieve a strong light intensity, so the content can be seen during daylight. Such screens

are often tailor-made but have standardized interfaces for access and control. Connecting a computer for showing content often works simply via standard DVI (DVI 1999) or VGA (VGA 2007) connection. In some cases, though, a rather complex adaptor technology may be involved to connect and control the displays, and thus unique specifications may exist on how to access them. For example, the large public display in Times Square used in Manhattan Story Mashup was of such nature. We could not connect our laptop or servers directly to the display system. Instead, we had to install ready-made videos on the operator's control machine, in order to show moving image material on the display. Further, the dynamic story-images that we showed were fetched from our own webserver in cycles and were placed on their own control machine.

Video projections are evolving to create large-scale displays. Video projectors are becoming smaller, while the light intensity and resolution increases. The technologies in use are LCD and DLP (LDC projector 2007; DLP technology 1987). The DLP technology offers a better black contrast and smoother colors, which makes it useful for large-scale outdoor projections. The LCD technology has stronger color contrast and is often used for office projections. A problem with both of these technologies is the limited lifetime of their expensive light bulbs. While office projectors typically have a light intensity of 1500–3000 ANSI Lumens and weigh 1–3 kg, the outdoor projectors are heavier and come with 10 000 ANSI Lumens or more, including optical lenses to adjust the size and distance of the projection. Nevertheless, large outdoor projections can also be achieved during darkness with a rather small DLP-type projector. MobiSpray, as an example, uses for its large-scale projections a small, portable 3000-ANSI-Lumens, 26 x 8 x 18 cm–sized, 1,6 kg video projector that in darkness nicely lights up a 30 x 20 m surface on a building.

The latest development in the field of video projector technology is the so-called pico-projector. Current models offer 10–30 ANSI Lumens through LED technology. This guarantees a long lifetime for the device. The model 3M MPro110 is 115 x 50 x 22 mm and weighs 152 g. It fits easily into a pocket and can be connected to a computer via VGA cable, or to a mobile phone via 'Video In' using a cinch cable. Its battery lasts about 1 hour. In the near future, moreover, mobile phones will have pico-projectors built in. This suggests very

interesting developments that may turn applications like MobiSpray combined with pico-projectors into ubiquitous mobile graffiti toys.

4.1.6 WEB TECHNOLOGIES

Web technologies such as AJAX (AJAX 2009), Java Script (Java Script 1995), Php (Php 2006), Flash (Adobe Flash 2009) and Flash-video (Flashvideo 2002) are useful for developing client-server solutions that support dynamic web and media content. These technologies allow creating tailor-made client and server applications. For instance, Manhattan Story Mashup (the storytelling website) was made of HTML pages supported by Java Script that communicated via AJAX (AJAX 2009). The server was programmed entirely in Python (Python 2009) and handled, among many other things, the game logic and the image processing of merging text with images. In MobiLenin, the server was programmed in Php (Php 2006) to handle the voting mechanism and to communicate with the connected mobile phones. Since MobiToss involved a front end for its web part in order to watch the outcoming video clips in a browser, a simple HTML website with integrated Php script was sufficient. The setup also facilitated a flash video player.

4.2 SOFTWARE TOOLS

The following paragraphs describe software tools that are relevant for building mobile interactive systems. Some of these were used for creating the mobile art applications in this study.

4.2.1 PYTHON PROGRAMMING LANGUAGE AND PYTHON FOR S60

Python (Python 2009) is a dynamic, object-oriented, open-source computer programming language. It can be used for many kinds of software development, for instance to create stand-alone programs, server software or scripted applications. Python is often used for prototyping and teaching introductory programming classes. It can be learned in a few days and offers strong support for integration

with other languages and tools. Python comes with extensive standard libraries. It is used by hundreds of thousands of developers around the globe.

Python runs on most common platforms in use, including Windows, Mac OS X, Linux/Unix, OS/2, Amiga, Palm Handhelds and Nokia mobile phones. It has also been ported to Java and .NET virtual machines. Python is an interpreted programming language and combines remarkable power with very clear syntax. It has modules, classes, exceptions, very high-level dynamic data types and dynamic typing.

Python was created by Guido van Rossum and is distributed under an OSI-approved open-source license that makes it free to use, even for commercial products. The Python Software Foundation (PSF) holds and protects the intellectual property rights behind Python.

Python for S60 or PyS60 (Scheible and Tuulos 2007) brings Python to the Symbian mobile platform. It supports many of the Python Standard Library modules but has in addition a number of mobile platform–specific modules that allow using native GUI widgets, Bluetooth, networking, GSM location information, GPS reading, SMS messaging, motion sensor, access to camera for taking photos or recording video and playback of sounds. Nokia creates the Python bindings for their S60 platform, which is based on the Symbian OS. Compared to other languages like Java or Action script, PyS60 is not sandboxed,instead providing direct access to the OS and a rich set of open APIs. In comparison with C++, it makes developing mobile applications “easy” and “fast”, plus it is quick to learn, even for novice programmers. PyS60 allows the artist or designer to focus on ideas and concepts. Its rich set of programmable mobile-phone features allows creating application functionalities required from a design as well as a technical perspective.

Though PyS60 is limited to building mobile-phone applications, it can be connected seamlessly to server and PC applications and systems, due to its wide range of communication protocols, among them 3G, GPRS, wi-fi and Bluetooth. Thus one is able to couple mobile with desktop or web applications, or both combined, for example with applications such as Max/Msp Jitter, Director, Pygame, Processing, Apple script, NodeBox and VVVV (see paragraphs below). These can be used in order to build client-server mechanisms,

enabling the mobile device to serve as input device, control device or capturing tool.

4.2.2 MULTIMEDIA CODING AND AUTHORING TOOLS

MAX/MSP JITTER

MAX/MSP Jitter is a tool for creating software to handle real-time audio and video. It allows building working solutions very quickly, due to its graphical UI. But it also has some shortcomings in its scripting support. It is available for MAC and Windows platforms.

ADOBE DIRECTOR

Adobe's software tool 'Director' offers a full-fletched multimedia-authoring environment that has the advantage of accessing all media elements via the scripting languages Lingo and Java script. It runs preferably as a stand-alone application but can be deployed to the Internet via a plug-in called 'shockwave' (Adobe shockwave 2009). Director is available for MAC and Windows platforms.

PYGAME

Pygame is open-source software that consists of a set of Python modules designed for the writing of games. It allows creating fully featured games and multimedia programs in the Python programming language. Pygame is highly portable and runs on nearly every platform and operating system, integrating easily with its own server software. In the case of MobiSpray, this was especially useful, since it allowed writing the entire system—including the mobile client and the server applications—in Python.

VVVV

VVVV (VVVV 2008) is a toolkit for real-time video synthesis. It is designed to facilitate the handling of large media environments that consist of physical interfaces, real-time motion graphics, audio and video. VVVV employs a visual programming interface for easy prototyping and development. VVVV is free for noncommercial use.

NODEBOX

NodeBox (NodeBox 2002) is a Mac OS X application for creating two-dimensional visuals—whether static, animated or interactive—using Python. The visuals can be exported as PDFs or QuickTime movies. NodeBox is free and open source.

QT

Qt (Qt 2008) is a cross-platform application and UI framework. Using Qt, one can write applications once and deploy them across desktop, mobile and embedded operating systems without rewriting the source code. Qt aims to enable UI and application developers to create a better user experience.

PURE DATA

Pure data (Pure data 2008) is a real-time graphical programming environment for audio, video and graphical processing. It offers features comparable to those of MAX/MSP Jitter, but it is open-source software. Pure data is available for Windows, IRIX, GNU/Linux, BSD and MacOS.

SUPERCOLLIDER

SuperCollider (SuperCollider 2008) is an environment and programming language for real-time audio synthesis and algorithmic composition. It provides an interpreted object-oriented language which functions as a network client to a state-of-the-art, real-time sound synthesis server.

FLASH

Adobe Flash (Adobe Flash 2009) is a multimedia platform that has become a popular method for adding animation and interactivity to web pages. Flash is commonly used to create various web page components, to integrate video into web pages and, more recently, to develop rich Internet applications. Flash uses the scripting language ActionScript (ActionScript 2009).

SILVERLIGHT

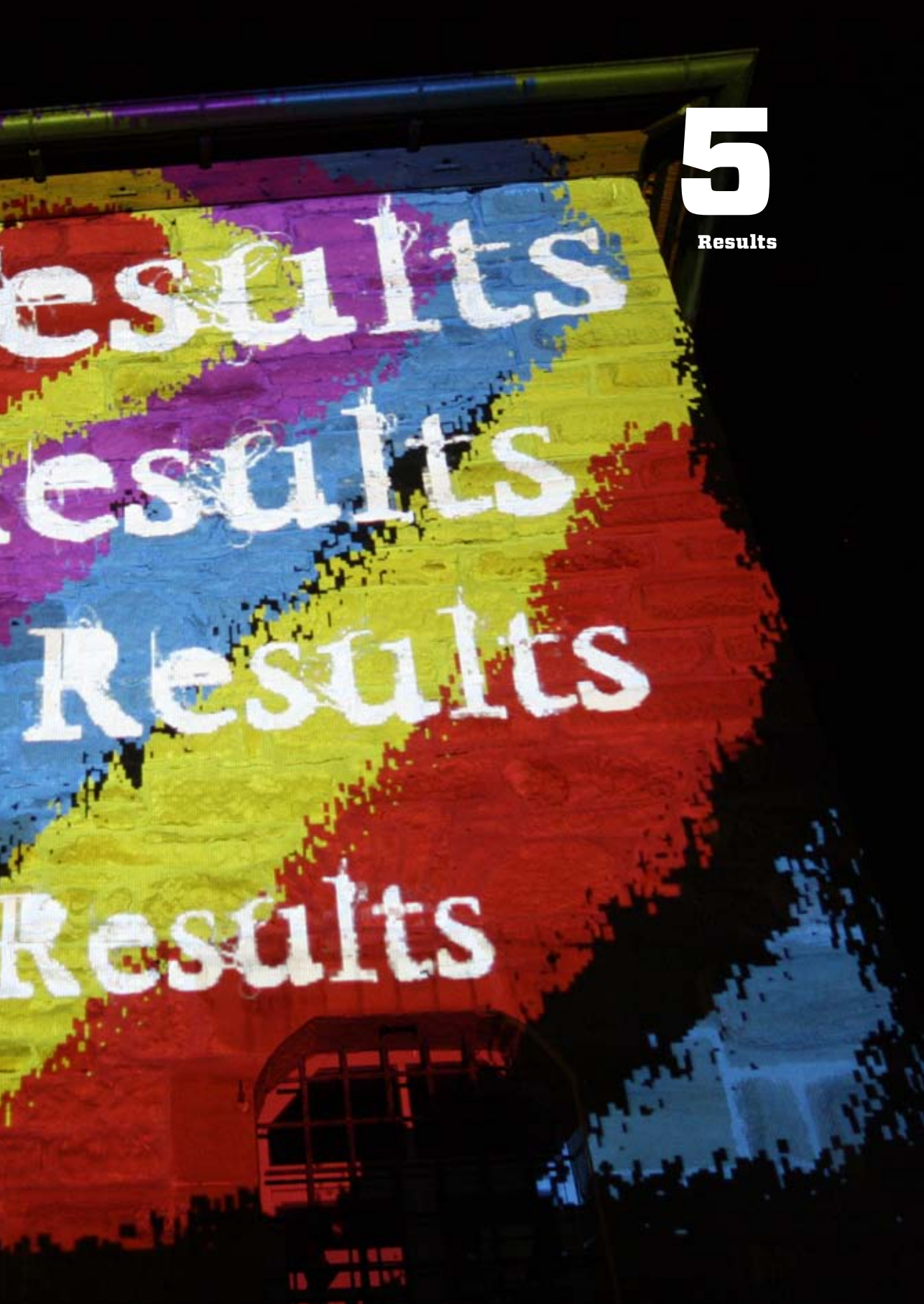
With Microsoft's Silverlight (Silverlight 2007), one can create rich web applications that run on Mac OS, Windows and Linux.

PROCESSING

Processing is an open-source programming language and environment for people who want to program images, animation and interactions. It is used for prototyping and production. It was created to teach fundamentals of computer programming within a visual context and to serve as a software sketchbook and professional production tool. Processing is free to download and available for GNU/Linux, Mac OS X, and Windows.

FFMPEG

FFMPEG (Ffmpeg 2007) is encoding software that is server-side scriptable. It can handle video conversion in multiple steps, from Quicktime (Quicktime 2008) to Flashvideo (Flashvideo 2002) to mobile video and more. It was used in MobiToss to convert videos into different formats.



5

Results

5 Results

5.1 OVERVIEW

This chapter presents a synthesis of the key findings and observations that this research work has produced. It focuses on concepts and categories emerging across all four of the mobile art applications developed for the research. The findings inform the process and practice of designing future mobile interactive systems with multimodal interfaces and a gaming or artistic component at their core.

The results chapter answers the three main questions of this dissertation:

i) How to design multimodal interfaces for creating and sharing artistic expressions?
ii) How to create engaging experiences with these interfaces?
iii) What do personal mobile phones have to offer in this context?

The results chapter is divided into four subchapters. The first subchapter presents, in addition to this overview, the novel technology outcomes of this research and the roles I played in each of the mobile art application projects. It further reports on the developed creative design and innovation methodology and looks at the research phases and artistic motives of this work.

The second subchapter is concerned with the research question 'How to design multimodal interfaces for creating and sharing artistic expressions?' It provides answers by looking at the key concepts that have evolved over time from work on the four mobile art applications.

The third subchapter addresses the research question 'How to create engaging experiences with multimodal interfaces?' It provides an overview of the patterns and key factors found, which have contributed to the creation of social experiences across the projects.

The last subchapter provides answers to the research question 'What do personal mobile phones have to offer in this context (of mobile interactive systems and multimodal interface design)?' It lists a set of key roles that personal mobile phones play in this context.

5.1.1 NOVEL MOBILE ART APPLICATIONS

This dissertation has produced novel technology outcomes in the form of four fully working prototypes featuring new technical concepts that build on each other and point to future mobile interactive systems design.

MOBILENIN provides a novel and creative technology solution for coupling multimedia art with a nonconventional distributed human-computer interface, for multi-user interactive entertainment. MobiLenin was entirely created by myself, including concept design, implementation and multimedia content.

MOBITOSS provides a novel application for creating and sharing mobile multimedia art with an off-the-shelf mobile phone equipped with built-in accelerometer sensors allowing gesture control. MobiToss was entirely created by myself, including concept design and implementation.

MANHATTAN STORY MASHUP (MSM) provides a novel technology solution that melds the Web, camera phones and a large public display into a collaborative street art authoring system. The concept design of MSM was done by myself, while Ville Tuulos of Nokia did the technical implementation.

MOBISPRAY provides a novel interactive system for creating ubiquitous ephemeral digital art. The mobile phone is employed as a virtual spray can to spray dabs of digital paint onto the physical environment via large-scale projections. MobiSpray was entirely created by myself, including concept design and implementation.

5.1.2 DESIGN METHODOLOGY OUTCOMES

The design methodology comprises the creative design and innovation process that was deployed in designing the reported applications. Chapter 3, 'Design process,' explains details of the entire process, laying out a creative practice for designing modern mobile-phone applications for rich human experience. The novelty of this design process lies in its proposal of a rapid prototyping approach that uses Python for S60 (PyS60) combined with a self-developed toolkit (so-called 'creative mobile toolkit') to support experience prototyping. This constructs practical means for fast experience prototyping, especially in the design and deployment of multimodal

interfaces. The approach allows fully functional prototype applications to be placed into the hands of users quickly and makes it possible to study the experiences relevant to the users and to explore new art practices. The described process can be used as a tool to generate design innovations in the field of mobile interactive applications, mobile art tools and multimodal interface design.

This dissertation provides strong evidence of the power of iterative design for innovation on the mobile platform. It shows that innovations are not instantaneous, that they need iterative design. Each of the mobile art applications of this research has undergone numerous iteration cycles. This fact highlights that innovation can be accelerated by applying the creative PyS60 prototyping approach. Iterative design could prove too expensive with a heavier design process.

5.1.3 RESEARCH PHASES AND ARTISTIC DRIVERS

This section looks at the four different research phases of this work. It explains how the produced prototypes have come into existence, as well as what motivated their design and how knowledge gained from one prototype's development has contributed to the next prototype. Further subsections describe key design concepts that have evolved over time across the four research phases and explain how each application design has contributed to them.

In the **first phase**, I explored the 'interaction with public displays' and its applications. The prominent questions posed by literature are how to entice interaction with public displays (Brignull and Rogers 2003), how to design engaging activities for audience interaction (Rogers and Lindley 2004) and how to create a collaborative tool allowing numbers of people to contribute to a single goal (Paek et al. 2004). As a start, I implemented the MobiLenin application in order to find answers to these questions. My artistic idea was to build an interactive system that would generate its own unique artistic expression, which feeds people's emotions and sympathy to entice them to interact and collaboratively contribute to a single goal. I tried to create a unique but in itself coherent interactive system. I wanted it to become an interactive art piece that inspires people and reaches new heights of interactive experience. As a result, I built a system that allowed an unlimited number of users to interact with a

public screen, using their personal mobile phones. After having built the technical solution (using a creative design process deploying rapid prototyping with PyS60), the design was tested and validated in an authentic environment: a pub. The knowledge newly acquired from MobiLenin touched on how a personal mobile phone can affect engagement in stimulating social experiences and the phone's contribution to a multimodal system incorporating visual and auditory modalities. The first-phase results informed the design of the subsequent projects Manhattan Story Mashup, MobiToss and MobiSpray. The gained design understanding served as a starting point for the art- and technology-driven approach of this dissertation research.

In the **second phase**, I wanted to explore the findings from MobiLenin and take them further, namely seeking how to create and deploy dynamic content rather than static content for interaction, how to provide real-time collaborative action of 'building something together' (rather than interacting only with ready-time-based content) and how to use the mobile phone as an interaction device for more than just voting. I was also interested to see to what extent a real- and virtual-world context could be brought to my multimodal design approach. Some people from Nokia research had read about my MobiLenin project and asked me to join them as the artistic director of a project. This led to the design of the large-scale pervasive game MSM. It melds the Web, camera phones and a large public display in a real-time collaborative street-art platform. As a start, I needed to come up with an idea for a novel large-scale mobile interactive project to include the components web, mobile and public display. I proposed the artistic concept of digital storytelling, in which people on the Internet write stories that are illustrated by other people who photograph images to go with the stories. Inspired by the experiences of MobiLenin and informed by its rich set of findings, I wanted to design an art application whose players would go through a fun and engaging experience, live out their creativity and possibly generate some artistic expressions. The creative design process of rapid prototyping with PyS60 was used to build the application, including multiple cycles of user testing and iterative design. Running the Manhattan Story Mashup game in New York City, where we had 11 public displays available in Times Square, served as the main evaluation event. The successful experience of building a system that

combines mobile, web and public displays in a collaborative street-art platform, as well as testing the mobile phone as a facilitator for public performance, served as an inspiration for the MobiToss and MobiSpray projects. My eyes were opened to the potential creation of a rich variety of art, using a mobile device. The idea of making art in public space using the mobile phone began to gain prominence in my research, which I then explored further with MobiToss and MobiSpray.

In the **third phase** of my research, I wanted to build on the findings from MSM that showed that mobile phones are suitable for facilitating interaction with the physical environment, using the camera for sensing the urban surroundings. I had also observed that mobile phones enable public artistic performance by combining the Web, camera phones and large public displays in a street-art platform. I wanted to couple these concepts with some characteristics of MobiLenin and build an installation that could be used in a pub or during events. Because one of my general goals when designing interactive systems is to bring more human aspects into the digital realm, I was eager to explore and introduce gesture control as part of the multimodal interface. Thus I wanted to build a system that would incorporate the familiar gesture of 'throwing', along with simple hand movements, to produce an artifact. The result was the MobiToss installation.

In the **fourth phase** of my research work, I wanted to take my research on empowering mobile art to a whole new level. I wanted to break free from the traditional fixed, installed, public display setting prominent in most of the previous projects. I was interested in having the screen 'anywhere', on 'anything'; I was also interested in having any phone user become a creative person or artist. I believed these two ideas could lead to a new model for future ubiquitous application design. Having seen from MobiToss that mobile gesture control works in real time, that creating art with it in public space was perceived by people as a fun activity; and having gained much knowledge from previous projects, I proceeded to design and implement MobiSpray. Its artistic idea stems from my desire to change, through digital art, the appearance of the physical environment into something different, unexpected and unpredictable—but without inflicting any permanent or illicit change. To achieve this, I created a

system for imposing large-scale, ephemeral, digital artistic projections on the environment. They serve as a vehicle for experiencing space and time in new ways, drawing inspiration both from the artistic process itself and the final artistic outcome. The mobile phone as a virtual spray can for painting BIG anytime, anywhere, on anything became a reality.

5.2 DESIGNING MULTIMODAL INTERFACES FOR UBIQUITOUS SYSTEMS

This section looks at the results related to the research question how to design multimodal interfaces for creating and sharing artistic expressions? This dissertation shows that through designing multimodal interfaces for ubiquitous systems, one can create novel applications that enable interactive experiences, new art-driven activities and new forms of making digital art. Such interfaces empower the user to be creative, to experience new things, to make something and to interact with other people in new ways, but also to interact with the environment. The multimodal interfaces demonstrate what current technology allows us to do and what design directions can be taken. They show an evolutionary path for how practical hands-on usage of mobile-phone technology has shaped the outcome of the mobile art projects of this research. Let's look at a number of concepts found across the research projects that are relevant to designing multimodal interfaces for mobile interactive systems.

5.2.1 MOBILE MULTI-USER INTERACTION WITH PUBLIC DISPLAYS

The concept of mobile multi-user interaction with public displays is found in all the mobile art applications of this research. During the evaluation of the prototypes, a number of key characteristics emerged.

Hybrid interface: Combining the complementary strengths and weaknesses of public display and mobile phone. A hybrid interface allows combining the complementary strengths and weaknesses of both public and mobile display (e.g. MobiLenin, MobiToss). The

public display has strong conceptual power, due to its large screen size, and it 'negates' the small display of a mobile phone. However, the personal mobile phone allows for distributing access to a large single-user display.

Private return channel for delivering user-specific information. A private return channel— from the large display system to the mobile phones—can deliver confidential user-specific content, such as the winning coupon of a lottery (MobiLenin) or a video clip with encoded music (MobiToss), to help entice people to interact with the public display. This allows for addressing not only individual users but also subgroups.

Public screen as shared medium for collaborative creation. The public screen became a shared medium in all four prototypes of this research. In MobiSpray, the multi-user version allows the public screen to become a shared screen for collaborative input. It accommodates drawing by up to four people simultaneously, and the "canvas" can be split among users in three different ways: full canvas accessible to all users, i.e. one user can draw on top of another user's drawing; each user has own section; users are assigned sections that partially overlap. In MSM, the role of public display was that of a shared view to the game providing a feedback channel via which street players follow in real time how their collaboratively created photos are being interwoven into the various stories. In MobiToss, the public screen was the medium for sharing a created video clip with peers and others in close proximity.

5.2.2 MULTIMODAL INPUT TOOLS FOR SOCIAL WEBSITES

The so-called GENERATION C phenomenon (Generation C 2007) that has emerged in recent years refers to the avalanche of user-generated content on the Web. Terabytes of new texts, images, audio and video accumulate there at an ever-increasing rate. The underlying driver seems to be that we are all artists, but until now we neither had the personal drive nor the means to pursue an artist's goal. Therefore, there is a need for better tools to create, produce and participate. The findings of this research show that systems such as Manhattan Story Mashup, MobiToss and MobiSpray can serve as

new types of tools for creating novel forms of input to and participation in social websites.

Input tool for community websites. As a collaborative real-time publishing environment, MSM on one hand provides the story writers and photo hunters an opportunity to display their illustrated stories in Times Square, and also on the storytelling website, which in many ways can be considered a dynamic social website. The produced artifact in MobiToss is automatically uploaded to a dedicated community website, which collects the clips and makes them available to other users and to non-user friends. The website can be configured for creating event- and location-based collections.

5.2.3 TANGIBLE INTERFACES

In recent years, built-in motion sensors have become common in modern mobile phones. This work shows how they can be used to build tangible interfaces for creating and sharing artistic expressions.

Pointing mechanism. In MobiSpray, the mobile phone is employed as virtual spray can to spray dabs of digital paint onto the physical environment via large-scale projections. It uses the built-in motion sensor of a phone as a pointing mechanism for tracking hand movements in real time. This allows users to draw by moving the hand, without looking at the mobile phone but looking directly at the building or object—the 'painting outcome' itself—instead. Although MobiSpray's gesture-controlled pointing mechanism may sound clumsy, novice users typically learn it quickly and find painting with the virtual spray can natural.

Throwing digital media to a screen. In MobiToss, a mobile phone equipped with built-in accelerometer sensors allows gesture control for creating and sharing mobile multimedia art. The users first snap a photo or capture a video with the phone and then use a 'throwing' gesture to transfer the clip onto a large public display for instant viewing and manipulation by tilting the phone in different directions. Users perceived the throwing of mobile content onto a large screen as a fun activity. This supports the notion of bringing human aspects into the digital realm, in this case the arm movement and the familiar gesture of throwing.

5.2.4 AUGMENTING SPACES WITH DIFFERENT MODALITIES

Real-time interaction involving sophisticated transformation or representation of data is highly interesting. Augmenting spaces with different modalities allows mixing global and regional, private and public, multilayers of spaces and activities. We need to design new types of interfaces in a sophisticated way to meet the challenge. In MSM, the physical space of New York City (its modality is mobile; mobile players run around using their mobile devices to take photos) is combined with the Web (whose modality is Web—players sitting in front of their browsers) and the public display in Times Square (whose modality is large display—players can see resulting stories).

5.3 CREATING ENGAGING SOCIAL EXPERIENCES AND NEW ART PRACTICES

With multimodal interfaces we can enhance places based on social exchange. We can build social spaces that provide new activities and reasons for being in a place, where collective interactions happen in new ways. This research explored how creating and sharing of engaging artistic activities can contribute to this, thus answering the research question how to create engaging experiences through the use of multimodal interfaces? The research identified several patterns and social affordances that are relevant in this context.

I explored why and how people feel socially engaged in interactive experiences. MobiLenin, Manhattan Story Mashup, MobiToss and MobiSpray provided a rich setting for researching patterns and key factors. According to Bertelsen and colleagues (2004), conscious human action, always part of motivated activity, is carried out by nonconscious operations triggered by conditions in the environment and the structure of the action. Magerkurth et al. (2004) stated that many forms of entertainment (e.g., sports, board games) rely heavily on human factors in creating a joyful interaction experience. They also pointed out that face-to-face group settings with natural means of interaction between players inevitably create social situations. The richness of human-to-human interaction involving eye contact,

mimicry and gestures is far from being captured in the purely virtual game play of computer games.

This research identified the following patterns and key factors contributing to engagement in social experiences:

- Making creative and artistic expressions in public space with a mobile phone
- Fostering social dynamics through private and public GUIs
- Face-to-face interaction
- Awareness of what others in the co-located group do
- Real-time collaboration in combined physical and virtual spaces
- Interaction with real objects
- Purposeful interaction
- Rediscovering traditional art practices via modern technology tools
- Symbolic transformation, or combining spaces with different modalities

These patterns are grouped in the following sub sections.

5.3.1 MAKING CREATIVE AND ARTISTIC EXPRESSIONS IN PUBLIC SPACE WITH A MOBILE PHONE

Creating art with mobile phones in public space is an emerging form of artistic expression. This research shows that making art in public space can translate into highly engaging social experiences. The MobiToss application was made for creating and sharing mobile multimedia art in public space. Its evaluation showed that capturing and throwing mobile content onto a large screen and manipulating it with gesture control into an art piece was perceived as a fun activity. The concepts of 'me the artist' and 'my art piece creation' are very relevant to the users of MobiToss. Having these concepts, combined with the fact that the audience can join in easily, makes MobiToss a potential new form of participatory VJ tool or public performance system. Clearly, MobiToss provides an engaging experience to users. With MobiSpray, the created paintings on buildings or objects in the street can be seen as a form of street art. It allows creating ubiquitous

ephemeral digital art as it turns the mobile phone into a spray can to liberate and empower the artist to change the environment via large-scale artistic expressions. In most cases, this happens in the outdoor space, and spraying nondestructive graffiti may become a new form of public intervention. Highly engaging experiences were also involved in MSM, as it provided the story writers and photo hunters with an opportunity to create illustrated stories as collaborative work in the form of street art. A notable observation was that users were acting out keywords when they could not find a suitable object to photograph. Also, the shooting of photos was perceived as an engaging experience. The imagination was used and original ideas were produced during the taking of the photos. Players made an intellectual and emotional investment. These examples show that one can succeed in designing a mobile application in such a way that it triggers creativity and provides engaging social experiences while fostering the making of art in public space.

5.3.2 FOSTERING SOCIAL DYNAMICS THROUGH PRIVATE AND PUBLIC GUIS

Combining private and public GUIs into real-time hybrid interfaces fosters social dynamics, because it allows social interaction at both the personal and group level. This study shows that new and exciting forms of engaging experiences can emerge from developing systems with such hybrid interfaces. For example, a large display can serve as the shared public GUI for all users (e.g., the co-located group), while the personal mobile phone is the private input and output device (e.g., for entering private commands such as votes, to control data, to throw a picture and to receive private information such as winning coupons (MobiLenin) or a video clip (MobiToss). On one hand, this allows participation in a group activity in front of the public screen, as a shared experience; on the other hand, it provides a personal experience with private enjoyments and actions. Combining private and public GUIs into real-time hybrid interfaces allows creation of new types of applications in the field of ubiquitous computing, whether these are of the nature of games or of interactive art, or whether they relate to day-to-day activities.

5.3.3 FACE-TO-FACE INTERACTION

Mobile interactive applications incorporating hybrid interfaces can provide a setup for users to have direct face-to-face interaction with others during the joint, social, public group interaction. The richness of human-to-human interaction involving eye contact, mimicry and gestures can happen and can create social situations. For example, in MSM the players formed small groups to help each other in shooting photos; the face-to-face contacts were part of the fun.

5.3.4 AWARENESS OF WHAT OTHERS IN THE CO-LOCATED GROUP DO

For group collaboration to be generally considered successful, each member must maintain awareness of what the others are doing (Rogers and Lindley 2004). The selection of appropriate interactional resources is what enables group members to remain aware of what others are doing, enabling all to tune in to the various needs of collaborative action. With MobiLenin, I observed that people were sitting in groups of two to three, discussing with each other what was shown on the display and making jokes about it. The system indicated the start of the voting round to everyone simultaneously and thus helped prompt people to be aware of others' actions. In MSM, people were aware that others were playing at the same moment, as they had to compete for points, help each other out by forming groups and validate other players' photos. In this case, the game context yielded the appropriate interaction resources provided by the multimodal interface.

5.3.5 PURPOSEFUL INTERACTION

Both MobiLenin and MobiToss showed that a mobile interactive system must offer purposeful interaction: People need to see and understand instantly what is in it for them. This relates to transparency of what the system has to offer, as it is important that users understand how their input affects the interaction.

5.3.6 REAL-TIME COLLABORATION IN JOINT PHYSICAL AND VIRTUAL SPACES

Real-time collaboration is a key concept in enabling engaging social experiences. The crucial issue in the MSM system was to interface a physical and virtual space, jointly, at the same time. It combined the real space (downtown New York) and the virtual space (Internet), while collaborative action happened in real time across both spaces. The evaluation shows that in this particular case, the majority of Web players felt a sense of belonging to a joint, collaborative action contributing to a common goal. This stood in contrast to the mobile players, whose minority indicated that it was clear to them that the keywords were coming from the Web players' stories. MobiLenin empowers the users with joint authorship, to direct in real time the outcome of the large display. Its successful design speaks for collaborative action as enabler of engagement in social experiences. When MobiSpray was employed in multi-user mode, the artists had great fun together as they simultaneously worked collaboratively towards a common goal and destroyed each other's contributions.

5.3.7 MOBILE INTERACTION WITH OBJECTS

An important issue in this research is the introduction of mobile interaction with real objects in the physical environment, as this points to future uses of ubiquitous technology and future forms of interaction. MobiSpray shows how interaction with buildings and nature is realized with a phone, a laptop and a video projector. It allows the artist to 'paint' on these while roaming freely (walking, standing, lying) around the target object, far or near in the real physical space, looking directly at its surface to see how the painting appears in real time. MobiToss provides users an opportunity to interact with real objects by capturing something from the physical environment, through taking a photo or video of it and creating a visual expression of it.

5.3.8 REDISCOVERING TRADITIONAL ART PRACTICES WITH MODERN TECHNOLOGY TOOLS

As shown with MobiSpray, traditional art practices—in this case, painting—can be rediscovered with modern technology, whole new

dimensions being added: like painting BIG, anywhere, on anything. As the linen board is the canvas for a traditional painter and the brush is the painting tool, so is the physical environment the canvas and the mobile phone the painting tool for the MobiSpray artist.

5.3.9 SYMBOLIC TRANSFORMATION

Augmenting spaces with different modalities allows performing symbolic transformation, such as transforming or representing data in real time through interaction that involves users in a sophisticated way. As shown with MSM, the physical space in New York (the modality is mobile— mobile players run around using their mobile devices to shoot photos) is combined with the Web (whose modality is Web— players all are sitting in their homes in front of their browsers) and the public display in Times Square (whose modality is large display— players can see resulting stories). It is about changing information from one form to another across different spaces and modalities. In MSM, a keyword exists first in text form and is then transformed into an image through the visual thinking of the mobile player who takes a photo. This image is then digitally integrated into a visual story by imprinting a full sentence on the image, which is then added to a row with eight other images, generating a full story that is shown on the web browser and on a public display in Times Square.

Another example of symbolic transformation is performed in MobiToss. The physical environment is used as a source to capture an image or video for creating a manipulated clip as the resulting transformed artifact, which is shown on a public display and on the Web. In MobiSpray, a building or an object is transformed into an art piece by adding light-based projections on top of its existing surface. This study shows how symbolic transformation can be used as a means to create and design engaging social experiences. The given cases enable the user to think visually or, in game form, to create group interest, change one's way of seeing, interact with others or interact with a public display. Multimodal interface design for mobile interactive systems plays a crucial role in this respect.

5.4 THE FUTURE ROLE OF A PERSONAL MOBILE PHONE

This section provides answers related to the research question what do personal mobile phones have to offer in context of mobile interactive systems and multimodal interface design? It identifies a set of key roles that personal mobile phones offer in this context and points to future possible uses for these devices.

5.4.1 DISTRIBUTING CONTROL AND ACCESS

Personal mobile phones come in handy in terms of dispersing access and control, for example in facilitating multi-user interaction with a single public display, while traditionally such displays are limited to single-user interaction. MobiLenin demonstrated a solution for realizing multi-user interaction with a public display, using personal mobile phones.

5.4.2 PARTICIPATION IN REAL-TIME ACTIVITIES

The mobile phone provides a tool to participate in a real-time collaborative activity. For example, in MobiLenin, the phone has a role in deciding what to see as content on a large public display, effectively empowering the group with the joint authorship of the video. The mobile phone allows anonymous, wireless participation in a joint, social, public action. In MSM, the mobile phone serves as a participation tool in a large-scale, real-time, pervasive game.

5.4.3 SENSING OF URBAN ENVIRONMENT

The mobile phone is a tool for sensing the urban environment, not only by collecting location data with its GPS reader functionality, but also by taking photos and videos with its camera. In MSM, the camera provided a powerful way to collect interesting data from the physical world. It was used as a tool for hunting photos in response to received keywords, with the aim of illustrating stories with 'live images' from New York City.

Another example is MobiToss, which uses the camera for sensing the surroundings by taking photos and video as input to a base clip that is manipulated and turned into a music video clip.

5.4.4 ART TOOL

Due to its powerful and rich set of functionalities, a mobile phone has great potential to become an essential tool for generating many new forms of digital art. As this research demonstrates, it can acquire new purposes within various art-creation practices.

5.4.5 INNOVATION TOOL AND MEDIUM FOR ACCELERATING ITERATION OF DESIGNS

The mobile phone is a medium for accelerating iteration supporting innovation in the field of ubiquitous computing. With toolkits such as PyS60 and the 'creative mobile toolkit', users can create applications based on their own ideas and fitting their own needs. As this research shows, by adopting a creative design process incorporating rapid prototyping with a mobile device, one can foster time-conserving innovation.

5.5 SOCIETAL IMPLICATIONS

As smartphones become a new medium for creative people in the arts and design world, as well as for technically skilled users, the industry expects a 'user-driven' innovation era to dawn (Scheible and Tuulos 2007). A wide audience of people is eager to enter the mobile space. The creative design and innovation process described in this work provides practical means to navigate and operate in this field, as it helps to accelerate efforts with its artistic drive and rapid prototyping approach. Distributed innovation on the mobile platform is becoming a reality and in my opinion will be a cornerstone of the mobile-device manufacturing industry, service-provider business and ubiquitous technology domain. We can see evidence of this from Apple's iPhone business and its App store (Apple App store 2009). I have a personal vision of a big garden full of beautiful flowers, each

representing a novel mobile application created by a user addressing his or her own needs.

5.5.1 USER-DRIVEN INNOVATION PROCESS AND PRODUCTS MADE BY LEAD USERS

From my personal experience as a 'lead user' creating the applications reported in this study, I have sensed for some years already the powerful impact 'user-driven' innovation will have on future mobile space. I have summarized my thoughts on why user-driven innovation is so important and how it can work in this field, first for my book 'Mobile Python' (Scheible and Tuulos 2007) and now to include them here; I have done so because I believe they present a path for how innovation can be enabled in our society, as they provide understanding of how future mobile interactive application designs can be influenced by users. By sharing the knowledge I have gained and my experience designing mobile interactive systems using PyS60 rapid prototyping in workshops around the world, these thoughts have been amplified by seeing the many fruits of people's work and experience. The thinking is inspired by and based on Eric von Hippel's book 'Democratising innovation' (Von Hippel 2005), and I extend his thinking toward the mobile platform.

Von Hippel (2005) discusses a phenomenon in which users can generate innovation if a toolkit—based on a platform product—is given to them that allows them to create something that meets some need they have. He calls this 'distributed innovation' by 'lead users'. Lead users, he argues, have the following characteristics:

- They are ahead of the majority of users in their populations with respect to an important market trend, and so are experiencing needs today that will later be experienced by many other users.
- They know and understand their own needs very well.
- They are close to the 'real situations', so the products they develop will appeal to others, too.
- They may innovate if they want something that is not available on the market.

Although his empirical data was collected from other fields, von Hippel's arguments around his lead user theory match well with what I have experienced in practice, from outcomes of workshops with creative students learning prototyping with PyS60. I saw how the students instantly innovated and created novel applications based on their own ideas and fulfilling their own needs, but were ready to share their innovations.

Von Hippel (2005) explains that users who innovate can develop exactly what they want, rather than relying on manufacturers to act as their (very often imperfect) agents. It may be that the needs of local user communities differ, and so local lead users really may be the world's lead users with respect to their particular needs.

User-centered innovation process. Von Hippel argues that users generally have more accurate and more detailed models of their needs than manufacturers do. The information assets of some particular user will be close to what is required to develop a particular innovation. Users tend to develop innovations that are functionally novel, requiring a great deal of user-need information and use-context information for their development. Using PyS60 and the related creative design process and toolkit, users can program applications based on their interests and ideas,going so far as to integrate local cultural aspects. Users with rudimentary programming skills can innovate rapidly, iterating through new ideas.

Development of products by lead users. Von Hippel (2005) states studies show that many of the innovations reported by lead users are judged to be commercially attractive; some indeed have been commercialized. PyS60 allows lead users and creative minds to make 'proof of concept' of their own ideas, ideas that usually fulfill real needs and can potentially be shared with others. In my mobile programming workshops, I often ask people what they would like to do with their own phone, and almost everyone comes up with a unique idea.

5.5.2 CREATIVE MOBILE TOOLKIT

The ability of users to innovate is improving radically and rapidly through improved access to easy-to-use tools and richer innovation commons (Von Hippel 2005). Companies have learned to supply proprietary platform products that offer user-innovators a frame-

work upon which to develop 'kits and design tools ... that can serve as platforms upon which to develop and operate user-developed modifications". The Nokia S60 mobile platform has many open APIs that can be combined with the PyS60 and my 'creative mobile toolkit'. They together promote a rich set of features and phone functionalities in the form of a framework that creative users can tap into to develop and to innovate.

Since I made my 'creative mobile toolkit' openly available on the Internet in early 2006, thousands of people around the world have accessed my online tutorial website (Scheible 2006). It provides a large base of starting code, on which people can program their own ideas quickly and in a powerful manner. One can find nowadays many open-source projects on the Internet that contain code snippets originated from my online tutorial. (These projects come from Africa, Brazil, India, Iran, Saudi Arabia, Australia and the USA.) The PyS60 community has grown nicely in past years, and many people state that they had initially completed my tutorial, and only afterward hooked up to PyS60. This reflects the really pioneering role that this research work has had in the field.

5.5.3 DIY CULTURE AND OPEN SOURCE

Von Hippel (2005) states that for individual user-innovators, enjoyment of the innovation process can be important.

Motivation of lead-users. To program with PyS60 is often described by people as fun, since it generates rewards and motivation through a seamless process of iterative development and design, with instant coding, modifying and testing on the real phone in the real mobile network. People can easily learn how to start making their own mobile-phone applications; there is a minimal learning curve.

Sharing of innovations. According to von Hippel (2005), users often achieve widespread diffusion: That is, they often "freely reveal" what they have developed. Individual users can benefit from innovations developed and shared by others. Freely revealing users may benefit from enhancement of their reputations from positive network effects due to increased diffusion of their innovation. Creating new PyS60 modules and making them public for sharing with others is becoming a common activity in the PyS60 community.

6

Conclusions and future work

6 Conclusions and future work

In concrete ways, this dissertation presents a variety of mobile art applications that enable individuals to experience space and time in the physical environment in new ways and to let them draw inspiration both from an artistic process and final artistic outcome. The applications show how we can engage not only with the visual but also the auditory, kinesthetic and tactile modalities of multimodal interfaces, as part of ubiquitous computing systems. An important issue is that by designing multimodal interfaces, we can create places that become 'real' to people, places that invite and reward involvement. We can build social spaces that provide new activities and more reason to be in a place. As my work shows, social behavior can be positively influenced and completely new mechanisms can be designed with ubiquitous technologies,helping generate rich human social experiences. However, not every system works as positively in every circumstance, since every setting is defined by a number of specific, decisive factors. For accessing cultural and creative instances, this research shows that by designing mobile art applications, new art practices can be created that allow people to be engaged in new ways of creating cultural outcomes— empowering mobile art practice.

The contribution of this research work regarding interaction with public displays lies in showing that successful interaction models can be designed with multimodal interfaces, where mobile phones play a central role in the interaction.

While the prototype designs described in this dissertation show strong aspects of technical novelty, they also enable users to produce content in the form of creative and artistic output. Richly varied groups of people can thus become creators and receivers of cultural products.

The design thinking and its resulting approach that is part of the creative design and innovation process deployed, ignited the many creative and innovative ideas and concepts of this dissertation. These include evolving the role of the mobile phone: from, originally, a simple communication device, into an interaction device for public display interaction, and finally into an art tool for interacting with the physical environment. The novelty of the creative design and inno-

vation process lies in its proposal of a rapid prototyping approach using Python for S60 combined with a self-developed 'creative mobile toolkit' to extend experience prototyping. This constructs a practical means for realizing rapid experience prototyping.

This study shows that symbolic transformation can be used to create and design engaging social experiences, because it enables people to think visually or in game form and helps to create group interest, to change one's way of seeing, to pursue interaction with other people and to pursue interaction with a public display. Multimodal interface design and mobile interactive systems can play a crucial role here.

FUTURE WORK

The mobile art applications described in this dissertation point to a new era in digital creativity, as they show the strengths of future mobile interactive platforms. The key points are providing engaging experiences of mass participation both locally and physically distributed; enabling creativity; and promoting real-time interaction not only between 'people and people' or 'people and machines' but also between 'people and things' such as nature, buildings, objects, the physical environment generally. These forthcoming approaches will lead to designs and implementations of new mobile interaction platforms, which eventually will lead us to new free-time activity forms and also new ways of working and living an art- and culture-inspired lifestyle. As a result, new business models in the mobile domain will emerge. Some concepts that could attach, for example, to MobiSpray are media activism, urban-planning simulation, theater performance and music performance.

DIY culture and open source. Combining open-source applications based on user ideas will increasingly open new opportunities for the masses to be creative in new ways and to engage in real-time physical activities not experienced before—simply because the technology was not there. We have recently, for example, seen the arrival of a mobile pico-projector of the size of a mobile phone. In the near future, the mobile devices on the market will have a builtin projector. This will most likely interest the graffiti artist, who can use it to follow a passion in new ways, and it will at the same time pave the way to new mobile art practices and movements. Combine a built-in

projector with GPS positioning and the ability to take both photos of final sprayings and video of the process of creating the art piece, and artists will be able to disseminate their work on the Internet and provide the location data of the physical location. Visitors to certain places may then be able to fetch and view the digital spray paintings on their mobile devices and see what others have created.

Green mobile art. Equipping a spectator crowd to generate electricity for computers and other electrical devices as part of guerrilla art practice might be feasible, as the audience could become part of collaborative artwork creation. This approach could be used when building a cluster of MobiSpray units with multiple projectors, for painting whole neighborhoods of a city in a flash mob manner (Flash mob 2003).

Placing advertisements into user-generated content. Some of the resulting content produced by the prototype applications of this research could possibly be coupled with commercial content. Encoding brand labels and music into user-generated mobile multimedia art clips for placement into people's phones as well as uploading to public sharing websites—after they have been created by a user in the first place—seems to be highly viable from a commercial perspective. As shown with MobiToss, this is achievable with a mobile interactive system. It offers great opportunities for placing advertisements in a new way. The illustrated stories of MSM could automatically be enriched with branding content. Or, the live drawings of MobiSpray could carry advertisements, either injected into the projection or placed inside the photos that are taken from the resulting paintings (which are uploaded to a sharing website). This suggests that future mobile interactive systems for entertainment or creating art hold strong business potential.

7

Articles
#1-5

Article 1:

"MobiLenin – Combining a Multi-Track Music Video, Personal Mobile Phones and a Public Display Into Multi-User Interactive Entertainment"

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ABSTRACT

This paper introduces a novel and creative approach for coupling multimedia art with a non-conventional distributed human-computer interface for multi-user interactive entertainment. The proposed MobiLenin system allows a group of people to interact simultaneously with a multi-track music video shown on a large public display using their personal mobile phones, effectively empowering the group with the joint authorship of the video. The system is realized with a client-server architecture, which includes server-driven real-time control of the client UI to guarantee ease of use and a lottery mechanism as an incentive for interaction. Our analysis of the findings of an empirical user evaluation conducted in a true environment of use shows that the MobiLenin system is successful, addressing many of the challenges identified in the literature. The proposed system offers a new form of interactive entertainment for pubs and other public places, and the underlying architecture provides a framework for realizing similar installations with different types of multimedia content.

CATEGORIES AND SUBJECT DESCRIPTORS

H.5.1 [**Information Interfaces and Presentation]:** Multimedia Information Systems – *evaluation and methodology, video.* H.5.2 [**Information Interfaces and Presentation]:** User Interfaces – *evaluation and methodology, input devices and strategies, interaction styles.* H.5.3

[**Information Interfaces and Presentation**]: Group and Organization Interfaces **-** *collaborative computing, computer-supported cooperative work, evaluation and methodology*.

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GENERAL TERMS
Design, Experimentation, Human Factors.

KEYWORDS
Multimedia art, hybrid interfaces, experimental evaluation.

1. INTRODUCTION

This work introduces the MobiLenin system which combines a multi-track music video with personal mobile phones and a public display into interactive art for the purpose of enticing social interaction between people.

According to Tosa [22], interactive art can be thought of as an emotion and sympathy interface, and interactive art is a component that provides sympathy with communications. Adams and Moussouri [1] define the interactive experience as something that can actively involve the visitor physically, intellectually, emotionally, and/or socially. Ryan [20] claims that an interactive medium opens its world after the user has made a significant intellectual and emotional investment. According to Maynes-Aminzade *et al.* [12], the greatest challenge does not lie in developing the technology for audience interaction, but in designing engaging activities.

In previous related works people have been able to control onscreen activity by leaning left and right in their seats to steer a race

car or move a paddle in the video game Pong, or by batting a beach ball while its shadow is used as a pointing device, or by pointing laser pointers at the screen [12]. In the Cinematrix Interactive Entertainment System [9] the audience members can participate interactively in activities such as maze navigation and opinion polling by displaying the red or the green side of a paddle. Since then relatively little progress has been made in the study of audience interaction [12].

Churchill *et al.* [6] argue that there are significant opportunities around the corner for distribution of interactive multimedia digital content designed for social networking and entertainment. Rogers and Lindley [18] state that there has been little research on how deploying public displays in different places invites certain kinds of social interactions. Instilling a sense of community is one motivation in situating large interactive displays in a variety of work and public places [18][7]. According to Paek *et al.* [14], interactive shared displays are most suited for certain types of applications, including "collaborative tools allowing multiple people to contribute to a single goal", and "arena applications involving competitive interaction". The MobiLenin system incorporates both of them to instill a sense of community and to entice social interaction among the users.

Vogel *et al.* [23] present the questions what kind of input and interface technologies do we need to develop to allow for effective interaction with large public displays? Many large display systems are currently single-user based and require users to take turns when interacting with them. However, there is a growing body of work investigating the use of multi-user interactive displays [4]. Maynes-Aminzade *et al.* [12] state that systems enabling large audiences to interact offer numerous possibilities for entertainment, but most research on interaction techniques focuses on single users or on small groups.

Magerkurth *et al.* [10] propose to augment traditional entertainment technology with social and physical elements to form e.g. a new class of hybrid gaming applications. This leads to a thought that mobile devices could be employed for this purpose. Reid *et al.* [16] report Schminky, a musical game where a PDA is used to interact with other players over a WLAN (Wireless Local Area Network) in a café.

The MobiLenin system offers a solution for realizing multi-user interaction with a public display using personal mobile phones. Pub-

lic displays and personal mobile phones make an interesting couple in terms of strengths and weaknesses. While shared displays typically offer greater conceptual power and larger presentation space, they often limit interaction to one user at a time. Personal mobile phones, on the other hand, disperse control and access to participating users, though limited conceptual power and smaller screen sizes often hinder dynamic interaction. Thus, connecting shared displays to personal mobile phones is an obvious way to leverage the best of both worlds [15].

One of the main challenges associated with interactive public displays is how to entice people to interact with them [3]? Agamanolis [2] concluded that half the battle in designing an interactive situated or public display is designing how the display will invite that interaction. Churchill *et al*. [6] found that users needed constant encouragement and demonstration to interact with the interactive public display. The MobiLenin system employs a lottery mechanism as an incentive for interaction.

We see that there is a need for designing engaging activities which make the users feel invited, interested and encouraged to interact. At the same time they have to have a reason to focus on what is shown on the public display. To rise to the challenge, we present the MobiLenin system, which builds on the combination of multimedia art, a public display, personal mobile phones and a client-server architecture. The principal idea of the MobiLenin system is that each user can with his/her personal mobile phone interact with an interactive multi-track music video shown on a public display. Each user can individually vote for one of the tracks by selecting the corresponding choice from the menu in the mobile phone application, and the track receiving most votes is shown. Thus, the MobiLenin system empowers the users with a joint authorship of the interactive art piece. As an incentive for interaction, the system contains a lottery mechanism which under adjustable circumstances chooses a winner among the users having voted in a given voting interval.

This paper is organized as follows. Section 2 describes the MobiLenin system. Section 3 presents the experimental user evaluation of the system in a true environment of use. Section 4 provides an in-depth analysis in regard to design issues, social experience and collaborative aspects. Section 5 summarizes our major findings for

future work, and explains how the MobiLenin architecture could be used for developing other artistic concepts.

2. THE MOBILENIN SYSTEM

2.1 ARTISTIC MOTIVATION

My (the lead author's) motivation as a music, new media artist and engineer was to create an interactive technology system that gives the audience the possibility to engage in a new way in my live show - simply by interacting with the music and video on a large screen. The idea is to enhance people's concert experience by allowing them to interact with the artist in the virtual domain (display). Through the virtual domain people can interact with attributes and scenarios (e.g. turn the artist into a skeleton) which can never be offered in the physical domain on stage - simply due to the physical limitations.

The MobiLenin system has its roots in two previous interactive art pieces, which I have created and performed on stage. In the first installation shouting and clapping of a crowd of people was used to change the tracks of a multi-track music video shown on a public display. This was done via measuring the sound input level (volume): the louder the shouting and clapping got, the wilder the performance of the music artist in the video. Field tests showed that the system generated strong group participation and dynamic group behaviour. In the second installation a large green coloured ball filled with air was thrown into the crowd of people. The position of the ball was estimated with a camera based tracking system and mapped to a certain interaction event that resulted in changes in the content of the public display. The MobiLenin system is the third iteration, providing a much richer set of features including empowering a group of users with the joint authorship of the art piece.

The system should be able to absorb the energy and atmospheric state of the audience through their interaction, so that a feedback loop occurs. The design of the system should be such that it can be used for large audiences but also in pubs for small groups and co-located group action in public events. On one hand the interaction affordance should offer elements of collaboration for large but also small crowds. At the same time there should be an individual back-

channel to people to reward them for their participation in the interaction (e.g. lottery - winning a CD). The interaction should trigger social engagement with other people and be fun and easy to use.

The system should generate its own unique artistic expression which feeds to people's emotion and sympathy. It should also give them a fresh and positive experience that fits to the brand of the music and appearance of the artist.

By providing my own music and producing the music video (interactive art) as well as doing the system design, the interaction design as well as the coding of the client server system and the mobile application for the MobiLenin system, I tried to use my artistic approaches to create a unique but in itself coherent interactive system. Through this system the nature and expression of my art should reach people's emotions and mind.

By using my engineering skills in combination with my skills for producing multimedia content and writing original songs - namely composing music, writing lyrics, producing music and doing live performance as well as video production - I try to jump to new levels of developing novel interactive systems and interactive art pieces that inspires people to carry them to new heights of interactive experiences. The MobiLenin system is one of the first outcomes of this motivation.

The artistic aspects of this interactive art work are reflected in its appearance, the production process and the experience design. On one hand in the performance style and the aesthetics of appearance of me as the music artist in the video – namely through acting that allows people to naturally connect with me when interacting with me on the public display (non real). On the other hand in the music composition that I created to stimulate people's mood and to entertain them. Also, the variety of experimental video techniques used to produce the video as well as putting together the various bits and pieces into a unique, in itself coherent interactive system, is parts of the artistic expression.

2.2 SYSTEM ARCHITECTURE

The MobiLenin system is realized with a client-server architecture which comprises of three components: a Symbian client application

running on a mobile phone, a server running on a PC, and a large public display showing the music video.

There are several reasons why the personal mobile phone is a suitable user device for our purpose. First, they are ubiquitous, as practically everyone has one. Second, they allow anonymous, wireless and mobile participation in a joint social public group interaction. Third, the mobile phone provides a reliable return channel for delivering confidential user specific information back to the user, such as the winning coupon of a lottery.

The client is implemented in Python following the Nokia Series 60 UI conventions. Each client is connected to the server via HTTP over a GPRS (General Packet Radio Service) data connection, which is supported practically by all available phones. We are not using Bluetooth connectivity, for then the server (master) would be able to connect to at most seven clients (slaves) simultaneously. Further, Bluetooth would restrict participation to users within a limited spatial range of about 10 meter radius from the service point, while the current implementation allows participation from far away, for example throughout the whole arena of a big concert. The client on each phone has a unique ID by which the server can identify them, controlling the state (UI) of each client in real-time via HTTP.

The server is implemented in Macromedia Director using scripting language Lingo [24]. The scripts take care of functions such as driving the state diagram, counting votes, lottery mechanism, initiating the delivery of winning notifications, and controlling the QuickTime player with its multi-track video. The scripts also handle all graphic elements on the public display as well as the sound output. An additional external server component consisting of simple PhP scripts is placed in the internet, acting as a mediator between the public mobile data network and the PC running the server application. The communication between the two is done via HTTP. The external component also hosts the pictures of the lottery coupons to be fetched by the mobile devices upon initiation by the server.

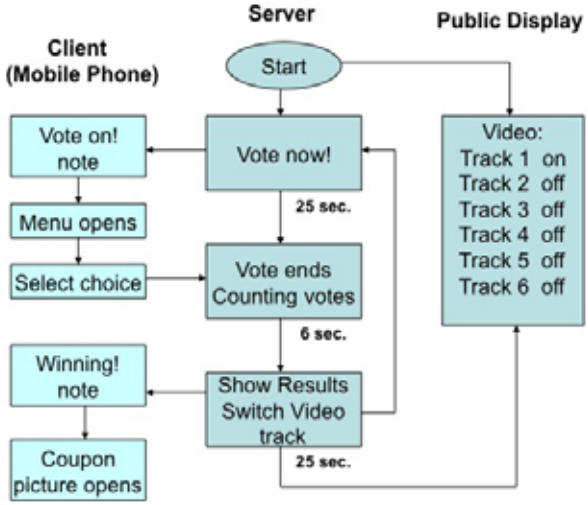

Figure 1. State diagram of the MobiLenin system.

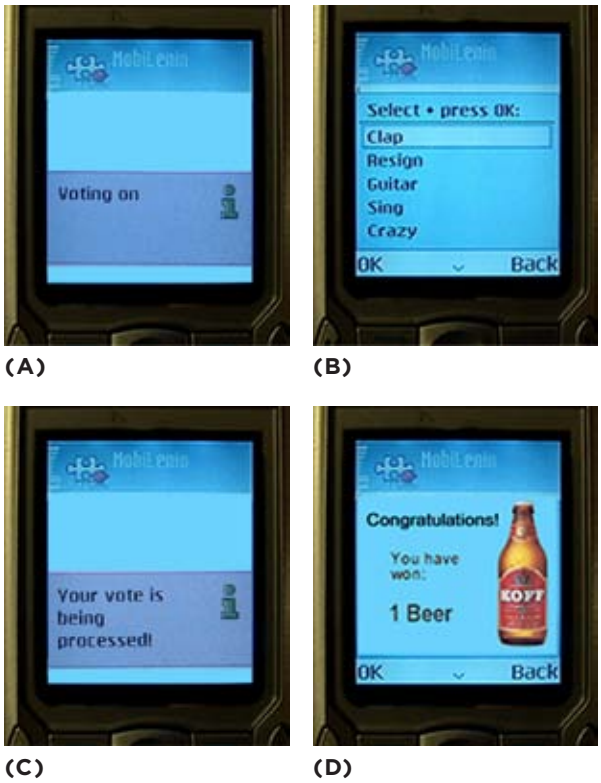

Figure 2. Screenshots of the client's UI: (a) the voting interval has started; (b) casting a vote; (c) the vote is acknowledged; (d) a coupon has been received upon winning in the lottery.

The large public display serves as the main user interface for the user's interaction. In addition to showing the music video, it indicates the start and end of a voting interval, the voting results, and notifies the audience of somebody winning in the lottery.

Figure 1 shows the state diagram of the system. When the voting interval starts, it is indicated in the client via a Series 60 popup note (Figure 2(a)) and shown on the public display ("Vote now!"). The server opens the voting menu in each client, so that a vote is cast by selecting one of the given menu choices (Figure 2(b)). If a vote is cast, it is acknowledged by the client (Figure 2(c)) and sent to the server. If the user wins in the lottery, a winning coupon is pushed to the client by the server and presented to the user (Figure 2(d)).

After the 25 second voting interval is over, the server switches off the voting menu in the client, and "Voting ends! Counting votes!" text is displayed both on client and the public display. The server counts the votes and after six seconds the result of the vote is displayed on the large display in form of six graphic bars, one for each voting option. The length of each bar corresponds to the proportion of votes each option received (Figure 3). The display of the result lasts 25 seconds and then a new voting interval starts.

Figure 3. A screenshot of the public display.

The six different options in the voting menu correspond to the six tracks in the multi-track music video. Only one track is visible at a given time, determined by the collective vote of the previous voting interval so that the track receiving most votes is shown. The change of the video track results in a non-linear perception of the video on the public display.

2.3 MULTI-TRACK MUSIC VIDEO

The main character in the music video is the lead author's artist alter-ego known as "Lenin's Godson", which explains where the name MobiLenin comes from: Mobile and Lenin. The "Ggogogo" song used in the music video is extracted from the artist's published albums, where it is available in three different versions of equal length: 1. a full version with guitar sound and singing; 2. a reduced version with guitar sound, but no singing; 3. a slim version with no guitar sound and no singing.

The music video employed in the MobiLenin system comprises of six tracks which are of precisely equal length and they are played in parallel and in sync, whereas only one track is visible at the time. The performance on the foreground is different in each track, whereas the background stays always the same. The six tracks are:

clap: he claps hands to the rhythm of the music (no voice, only slim music version with no guitar sound and no singing); *resign*: (no voice, just gestures, still slim music version with no guitar sound and no singing); *guitar*: he plays guitar (still no voice, reduced music version with guitar sound, but no singing); *sing*: he sings and plays guitar (now also the voice is on: full music version with guitar sound and singing); *crazy*: 'violent' performance (voice and full music version are on); *skeleton*: he turns into a skeleton (still playing guitar and singing with full music version on).

The foreground video for the six tracks was shot in a studio against a blue screen. Each of the five performing styles of the artist was separately filmed with the full length of the song, leading to the five foreground videos. The footage for the sixth track - the skeleton - was produced via a stop motion animation using a plastic toy skeleton as the model in front of the blue screen.

In order to portrait a strong presence of the performing artist in the video, it was shot from the front using one fixed camera position. The artist was filmed from knee to top so that he was placed in the middle of the frame. This single position of the artist served as the reference position point in the frame, for the purpose of producing a coherent outcome in all of the six video tracks. In each track the artist needed to appear in the same spot, the same size and occupy the same space in the frame, otherwise the change of the track in the final multi-track video would appear unnatural to the viewer.

The footage for the background video was shot on a busy street in the middle of heavy traffic, and edited into exactly the same length as the song. As the next step each of the six foreground videos was overlaid over the same background video using the bluescreening technique. This guarantees linearity of the background, i.e. keeping the background stable and coherent despite the foreground (performance style of the artist) being changed at any point of the music video during the interaction.

The multi-track video was generated with the QuickTime player, into which the six video tracks and the three music tracks were imported as parallel tracks. A single QuickTime file was produced where all video and music tracks are in sync, each corresponding to a single layer (parallel QuickTime track). Each track can be enabled or disabled in real-time via a scripting language such as Lingo in the Macromedia Director used in the MobiLenin server.

3. EXPERIMENTAL USER EVALUATION

The MobiLenin system was tested in a real world setting in a local restaurant. As illustrated in Figure 4, the public display was situated 4-8 meters from the users. Each user was given a Series 60 phone containing the client application, and shown how to start the client. Then the interactive music video was started and people could cast their votes in each voting interval.

Research data was collected with various methods. Qualitative data reflecting the user experience was collected with a questionnaire, which each test user filled in after the experiment. The questionnaire contained 21 statements on which the users were asked to answer on a 5-point scale 1 (disagree completely) – 5 (agree com-

pletely), and 13 open-ended questions. Five individual users and a group of four users were also video interviewed after the experiment.

Figure 4. User evaluation in a real world setting on-going.

Observation was carried out during the experiment with three video cameras so that one fixed camera shot a panorama of the whole experiment, another fixed camera recorded the public display and a mobile camera shot close-up footage of users. A digital camera was also employed for taking still photos. Test users were informed about the observation before the experiment.

Quantitative data was collected by logging in the server, for the purpose on computing statistics such as individual votes, vote counts and outcome, as well as lottery results.

14 test users (eight males and six females) participated in the experiment, and for the most part they were recruited on the spot. The age distribution was 3 of 18-24, 8 of age 25-34, and 3 of age 35+. Each willing test user was served a drink of his/her choice before the start of the experiment, and another optional drink was served upon returning the questionnaire.

The lottery mechanism was adjusted so that at least 9 votes needed to be cast in a given interval for the lottery to take place. If so then with a 50% probability a winner was selected among the users having voted in this interval. If a winner was selected, the prize was either a beer or a pizza with 50/50 chance. Test users were informed about the lottery mechanism before the experiment.

All 14 users used the system at the same time in a single session, during which the music video looped three times for a total duration of 11 minutes and 45 seconds. 13 voting intervals took place, with an average of 11 users casting their votes in each interval. The lottery system identified seven winners, of which two were awarded a pizza and five a beer.

A very clear general observation was that people enjoyed using the MobiLenin system. This was expressed by laughing, happy faces, good mood, and rowdy celebrations upon winning in the lottery. This shows that our system succeeded in designing an engaging activity by making users feel encouraged and invited to interact with a large display, which was identified as a major challenge in the literature review.

4. ANALYSIS OF FINDINGS

In the following we discuss various aspects of the MobiLenin system and the experimental evaluation, relating our findings with the relevant literature. For brevity we adopt the following notation: "Statement" (X/Y) means that *X* users agreed (answering either 4 or 5 on the 5-point scale) with "Statement" and *Y* users disagreed (answering either 1 or 2) with the statement in their questionnaire. *Test user's comments are printed in italic*.

4.1 SOCIAL SETTING

Past research on audience participatory systems shows that the physical and social setting is essential to interactive systems such as the MobiLenin system. According to Churchill *et al.* [6], the social setting drives the extent to which the technology is perceived as functional or playful or both.

Brignull *et al.* [4] used a large interactive situated display to provide a public interactive surface for the cooperative sharing and exchange of media in their Dynamo project. The users reported that the display promoted a social atmosphere and generated opportunities for people to engage with others that they would not normally talk to. Similar findings have been made also by others, as well [3][13].

Observations by Churchill *et al.* [6] of their Plasma Poster revealed that the physical and social setting has a strong effect on how and when people "interface" or interact with content. They maintain that the entire social and physical setting is the interface to the consumption of the content, not just the interface-as-display.

Maynes-Aminzade *et al.* [12] have conducted over 30 tests with 150 to 600 participants in each, which demonstrated that social involvement is more important than technological involvement. According to their findings, audiences become very emotionally involved in polls and trivia, particularly when the topic of the poll is a highly contested issue, or when several audience members believe they know the correct answer to a trivia question.

The participants' comments in the video interviews after the experiment indicate that the interaction experience with the MobiLenin system was perceived as a highly social and exciting experiment: *"It was pretty social actually, more social than I was expecting."; "I felt being part of the group, enjoyed the social side of the event."; "The most interesting thing for me to be here was to be a group, it was a social thing."; "There was time to make jokes in between, this was social happening."; "The experiment was exciting, it was thrilling, I liked it."* This shows that the MobiLenin system as an interactive entertainment generates a strong social setting and succeeds in designing engaging activities which has been identified as a major challenge in the literature.

In the following we discuss the potential factors contributing to the successful creation of the social setting.

CO-LOCATION. Magerkurth *et al.* [10] state that many forms of entertainment (e.g., sports and board games) heavily rely on human factors in creating a joyful interaction experience. Looking at computer games, they maintain that in terms of social richness today's co-located computer gaming is far behind other popular game types such as board games. The difference is attributed to board gaming sessions creating a much stronger social situation than a computer game session. They propose augmenting traditional entertainment technology with social and physical elements to form a new class of hybrid gaming applications. These hybrid applications should integrate the social dynamics of co-located groups with computer games via interfaces that do not distract from the group situation.

MobiLenin stimulates inter-personal social interaction in co-located groups in front of the public display, and the system supports the social dynamics of the groups with its easy to use interface. The system allows multiple users to cast individually anonymous votes for a common goal, which contributes towards a strong social experience as a group. Participants' responses after the experiment underlined the social interaction of the co-located groups*: "I felt I was part of the group."*; *"When you are in here you feel the size of the group, then it is quite nice to see what is coming on the screen."; "The most interesting thing for me to be here was to be a group, it was a social thing also that the whole group was not too big."; "It made me feel belonging to the group"; The experience was nice, group fun."* "This interaction experience would have been better if I would have been alone to interact with the display" (0/12).

FACE-TO-FACE CONTACT. Magerkurth *et al.* [10] point out that face-to-face group settings with natural means of interaction between players inevitably create social situations. The richness of human-to-human interaction involving eye contact, mimics, and gestures is far from being captured in the purely virtual game play of computer games. Direct face-to-face interaction should be enabled and new interfaces between the players and the virtual domain must be introduced. These new interfaces are to ensure both the group situation to remain socially adequate and the transition from and to the virtual domain to be performed effectively [10]. The mobile phone used in the MobiLenin as the interface to the virtual domain (public display) appears to be a suitable user device for such purpose, as it allows direct face-to-face interaction with other players during the joint social public group interaction.

AWARENESS OF WHAT OTHERS IN THE CO-LOCATED GROUP DO. Rogers and Lindley [18] state that the selection of appropriate interactional resources is what enables group members to keep aware of what each other is doing, enabling them to be tuned into the various needs of collaborative working. Further, for collaboration to be generally considered successful, each member must maintain awareness of what the others are doing. This underpins what our participants experienced: *"With a small group you feel you can really have feeling of voting. Otherwise it's like tv-chat and that's not so cool."; "If it is e.g. like a TV channel and the audience is too big, then it goes like these TV*

chats and it is not a big deal at all what is the result, but when you are in here you feel the size of the group, then it is quite nice to see what is coming on the screen".

We observed that people were sitting in small groups of 2-3 people, discussing among each other on what was shown on the display and making jokes about it. This shows that our system provides the means for people to be aware of what others are doing within the interaction experience.

PRIVATE AND PUBLIC GUIS TO FOSTER SOCIAL DYNAMICS. O'Hara *et al.* [14] tell that large displays in public spaces afford different forms of engagement with content. Magerkurth *et al.* [10] go further by stating that both private and public GUIs should be available to foster social dynamics. In order to create private, shared, and public information in the social domain, it is essential to provide additional private interfaces to the virtual domain. MobiLenin provides both public and private GUIs. The display serves as the public GUI for sharing public information. The personal mobile phones serve as the generic private input and output device for entering private commands (votes) and receiving private information (winning coupons).

The participants' feedback speaks in favour of combining a public display and personal mobile phones for interaction: "*Being in front of screen, having mobile phone in hand to interact with screen works and is the best way for this sort of interaction. It is easy because people are used to phone.*"; "*This system has huge potential in very many ways, e.g. use the same kind of idea in many different situations to have the chance to do the interaction with screen and mobile.*"

SPECTATOR VIEW. Reeves *et al.* [17] have explored how crafting interaction for public settings is affected by spectators. Churchill *et al.* [6] report that during the evaluation of their Plasma Poster in a community setting spectators watched people reading and interacting with content. Video recording of our experiment shows that the role of a spectator was a part of the social setting. People from all over the restaurant gathered close by the public display, watching the music video and the participants of the experiment, and contributing to the social atmosphere by laughing and shouting. The spectator view was also present among the participants, as demonstrated by the following comments: *"It is fun if you see how people are react-*

ing or when they are voting - it is something in common."; "It was fun to see the interaction of the people."; "It was fun to watch who wins."

DROP IN DROP OUT. MobiLenin allows people to join the interaction at any time, as well as refraining from it. This gives users the flexibility to follow their own agenda and moves. In their Schmink application Reid *et al*. [16] used PDA's for gaming in a café. As one important finding they report that the PDA allowed players to sit wherever they like, without invading the space of non-players, which made its impact on non-players less intrusive. Despite reservations about the intrusion of technology in public spaces, people value optional, spontaneous mechanisms to play co-located games. Their experience leads us to believe that such games should be designed so that they can be interleaved with other activities like drinking, eating, chatting, and phone calls. Dropping in and dropping out according to one's own agenda certainly is helpful in these situations.

4.2 EMPOWERING A GROUP OF USERS WITH THE JOINT AUTHORSHIP OF THE MULTIMEDIA CONTENT

According to Manninen [11], the non-linearity in games can provide some degree of authorship to the player, and thus enrich the interaction. The question is to what extent this is valid for video. The MobiLenin system empowers a group of users with the joint authorship of the art piece. Allowing people to make changes in real-time to the music video and to direct its outcome on the large display by majority voting seemed to entice them to interact, both with the public display and with each other.

People seemed to like to be empowered with the authorship. This came across by the creative and imaginative answers by the participants when they were asked if they would like to change something else in the video with the mobile phone, and if so, what would it be? Among the answers was: *"More instruments"; "Maybe clothes, dancing etc. to develop the character"; "More complex tasks"; "Constructing gradually an avatar with community would be nice"; "Different sort of music after a while. Other music instruments than guitar, maybe?"; "Music, clothes, the acting, background and more choices in voting menu"; "Maybe different kinds of music"; "I would have changed the setting, scene behind".*

However, when asked how they felt about having the possibility to influence the video in real time by their mobile phone, the participants had mixed feelings. While some users liked the mobile authorship: *"Fascinating, I could think the possibilities are endless on this field of mobile interaction. I will be looking forward to more interaction like this."; "The idea has a lot of potential."; "It was nice."*, some users tentatively refrained from it: *"It's nice, but in the video the content is more interesting. For me choosing things is not self value."; "Fun, on the other hand it could be annoying, frustrating, if the result is wrong in my opinion."*

Still, being empowered to make own selections about the visual appearance and the sound to affect the art piece motivated users: *"When just music was going on without singing - that was also one which really made a difference and I really felt it and noticed it."; "It is content and real clear visual differences and lots of choices, that is like what is nice for me."; "It was good to notice that the vote really made a difference"*. Similar answers were given to the question "What was it that you enjoyed most?": *"To make man singing, content matters."; "Social experience and Mr Lenin singing or going crazy!"; "The video was fun."; "The music was good."* Answers to the question "What kept your interest up to continue to vote?" also support empowering the user with the authorship: "*Different possibilities, so content*"; "*To see different actions in action.*"; "*Guessing what's next.*"; "*To see if I would guess the outcome.*"; "*If there would have been more choices, or for example some other mime too.*"

We can conclude that empowering the user with certain authorship to affect the outcome can create new types of interactive experiences for people.

When the users were asked with what type of content they would like to interact, we got a variety of answers: "*Connected with interests of people e.g. different music styles, pop, rock etc. so people could find and see what bunch of people you have there, who likes what.*"; "*Avatar, lot of different properties to construct the avatar, would be interesting to see if a group could construct it, so to change features to other parts of the avatar or environment.; Properties of funny things coming into the film.*"; "*Found it very funny to have the skeleton, it gave nice picture of innovativeness and humor.*"; "*Building up something gradually would be interesting.*"; "*Imagine night club, vote for next song and vid-*

eo and interact with that."; "*Trivia game to vote answer with group.*"; "*Music videos are nice, that inspires me.*"

We also argue that the personal mobile phone as the interface guarantees each user equal share of the joint authorship, in contrast to systems relying on motion tracking where the audience members have uneven degrees of control because people closer to the camera have a more pronounced effect on the interaction [9].

4.3 ENTICING INTERACTION WITH PUBLIC DISPLAY

The use of large interactive displays has an established history in supporting collaborative and group-based activities. Primarily, they have been used to support various cooperative activities that occur within meeting rooms, classrooms, offices and other workplaces. More recently, researchers have begun to situate large displays within communal and more informal settings [4]. Large-screen digital displays are becoming increasingly prevalent in public spaces, but currently most of them are minimally interactive and are designed for one-to-many interaction [6].

As we already discussed in the introduction, Churchill et al. [8] found that people needed constant encouragement and demonstration to interact with the public display. Similarly, Agamanolis [2] has noted that half the battle in designing an interactive situated or public display is designing how the display will invite that interaction. This means that a key issue is how to design the displays so that they invite interaction [2] and collaboration [19].

To entice interaction we employ the lottery mechanism, which according to our observations had a strong impact on the users' motivation to interact. Paek *et al.* [15] has identified that as an incentive, a lottery could notify random participants that they have won a prize. Our test users agreed: "I think the idea of having a lottery to win a pizza or a beer in such a system is good" (13/0). Lottery had a clear effect on the social interaction, for when a winner was announced on the public display, it stirred lots of excitement: "*The excitement, what happens next, who wins the lottery*". People were happy when their mobile phone indicated that they had won, raising their arms in the air, just like happy winners do, and then showing their received pizza or beer coupon to others nearby. However, it became clear that

the lottery was at best in supporting role in comparison to the interactive content in terms of enticing interaction.

Brignull *et al.* [4] mention that one of the reasons for the initial reluctance to use novel public display systems may be that it is not clear to the members of that community how they can integrate them with their existing practices. Another reason may be that people can be self conscious and inhibited when required to do new things and act out in a public arena. We circumvented this problem by deploying the trusted personal mobile phone as the user interface. It allows anonymous participation in the multi-user interaction with a familiar device, making people invited and uninhibited to interact.

Pacing the activity is one important aspect of the interaction. Punctuated deadlines give the audience a chance to succeed or fail; the rest periods give them a chance to contemplate, celebrate, and prepare for the next moment of tension [12]. In the MobiLenin system such deadlines are determined by the voting intervals controlled by the server, whose rhythm was found appropriate: "The voting interval was sufficiently long" (10/2). We noted that the time of waiting for the results created a dramatic moment for people during which they strongly socially engaged with each other. This moment can be used e.g. to build up dramaturgy within the interactive art experience. A satisfactory feeling was perceived when the result showed that their choice was found right. On the other, hand some participants stated that there is also a risk of getting frustrated if your wish of choice does not match with the majority vote enough often.

When asked how long the interaction could go on, test users responded: *"As long as you get new information on screen, or is not repetitive."; "At beginning when choices seemed to be wide enough, after a very short time one could know what are the different choices to make - knowing the spectrum, after that it became ok, I have seen it already"; "But if doing it again maybe after three times with same video it got a bit boring. So a new video might be good after second or third time or first time, I don't know, but something new."; "The content was ok for a first 10 minutes, but it was afterwards becoming boring."* These comments reflect the importance of the novelty value of the interactive content: the user has to be able to anticipate "something new" at the point of interaction.

4.4 SYSTEM DESIGN AND IMPLEMENTATION

We can identify a number of aspects in the design and implementation of the MobiLenin system which contribute towards the positive user experience.

EASE OF USE. Brignull *et al.* [4] state that it is important to provide an initial set of display-based interactions that are intuitive and can be easily and comfortably followed. Allowing users to engage with the display, without needing help or feeling self conscious, is a key concern when situating displays in communal spaces. We used the standard UI paradigm of the Nokia Series 60 platform, to produce a simple UI with which the users are already familiar thanks to their everyday mobile phone use. The usability was further enhanced by the server controlling the state of the client to prevent any navigation errors. "The system was easy to use." (13/1).

TRANSPARENCY OF WHAT THE SYSTEM HAS TO OFFER. It is important that audience members understand how their actions affect the game activity. They will not continue to participate in an activity if there is no immediately clear indication that they are affecting the game [12]. Sandin [21] states that in interactive systems it is vital that the participants quickly realise that they have control and understand what are the parameters of that control. In this way, the users can easily learn the simple relationships between their actions and the system itself. MobiLenin succeeds in addressing this challenge: "I felt it was clear from the beginning what the system has to offer me and how to interact." (9/4), "The system gave me a clear picture of the outcome of the group vote." (12/1).

CONSTANT BUT LIGHT FEEDBACK. The popup notes triggered by the server onto the client UI were found very useful in maintaining the interaction: "I found the popup notes useful on the phone that indicated 'voting on' or 'vote is processed'." (12/0). We can conclude that for an interactive system such as the MobiLenin system, the guidance of the individual user through the interaction process and constant feedback from the system is crucial in order to keep the user hooked up and encouraged in the interaction. But this guidance must be simple and light, for which a personal mobile phone is a potent solution.

MULTIPLE CHOICES IN INTERACTING. While designing the system, we contemplated offering the users only with the possibility to

vote for a gradual up/down change in the video, but thankfully we did not go for it: "6 voting choices in the menu were given - to have fewer choices would be better" (0/11). "It would have been more interesting to vote, if the system gave the chance to vote only for "up", "stay", "down" in order to influence the flow of the video" (0/10). The analysis of our video interviews shows that it is important for the user to be able to anticipate from the menu choices what comes next on the large display and that these choices reveal new aspects of the content - something new that holds a surprise value but also something that confirms what the user has anticipated: "*Seeing, if the thing that happened was the thing I voted for*".

MUSIC. Camurri *et al.* [5] describe how direct relationships can be established between certain parameters of music and the associations created by it. For example, a fast tempo is associated with various expressions of activity, excitement, happiness, potency, anger, and fear, while a slow tempo is associated with various expressions of sadness, calmness, dignity, and solemnity. Loud music may determine the perception of expressions of intensity, power, anger, and joy whereas soft music may be associated with tenderness, sadness, solemnity, and fear. Certainly, the song "Ggogogo" used in the interactive music video by artist Lenin's Godson is of positive, "good mood", "easy to listen" nature while the tempo is rather fast, but not too fast. This leads to the question on how relevant music is for the overall atmosphere and user experience of an interactive entertainment system such as the MobiLenin system.

5. DISCUSSION

We believe that new and exciting forms of interactive art can emerge by further developing hybrid virtual interfaces such as the MobiLenin system. We combined the private GUI of a personal mobile phone with the public GUI of a public display into a real-time hybrid interface which fosters the social dynamics of co-located groups without distracting the user. The personal mobile phones also disperse control, allowing multi-user interaction with a single public display, thus empowering a group of users with the joint authorship of the multimedia art piece. The system also contains a built-in lottery mechanism as an incentive for interaction.

Experimental evaluation in the true environment of use showed that the MobiLenin system succeeds in enticing social interaction at both personal and group level, addressing several of the challenges identified in the literature. The users embraced the joint authorship, which resulted in high social activity among small groups of people. Similarly, the users enjoyed the lottery mechanism: the announcement of the anonymous winner on the public display stirred plenty of general excitement, which then erupted in someone's personal celebration followed by congratulations from the group.

In addition to dispersing the control and facilitating the multi-user interaction with a single public display, employing personal mobile phone as the private GUI brings also other advantages. They are ubiquitous and as such remove the need for any additional, possibly application or service specific user devices. A personal mobile phone is the trusted device and it allows anonymous participation in a group activity, which both contribute towards people feeling invited and uninhibited to interact. Mobile phones also guarantee each user equal power in the interaction and provide a reliable return channel for delivering confidential user specific information back to the user.

Our study confirms that social involvement is much more important than technological involvement. While people are initially amazed at the technology allowing the interaction to occur, within 30 seconds they lose interest if the activity is not inherently entertaining [12]. Our test users commented that in order to keep their interest up in interacting with the music video for a longer time, the system would need to offer something new they have not seen before. Our conclusion is that the key lies in the production of content, so that the user is allowed with a sufficiently rich set of choices to choose from at different times and can anticipate "something new" at the point of interaction. One important issue in producing non-linear content is that the production might require more resources, since multiple tracks need to be produced of one and the same part.

5.1 FUTURE WORK

The MobiLenin system can be expanded in different ways by adopting different content and modifying the script of the interaction.

Other possible concepts include interactive storytelling, trivia and multi-player gaming, for example.

The MobiLenin system is scalable so that even large groups of people can interact with the public display and the content. We could ramp up the activity of the current setup into a much more versatile interaction pattern in a more dynamic setting of a live concert. Starting from simple majority votes for the next song to be performed, the interaction could be extended all the way to complex issues such as allowing the audience to interact with the parameters of individual instruments played by the musicians on stage.

The feedback channel provided by the private GUI of the mobile phone application allows addressing individual users or subgroups. For example, the system could ask only one fourth of the audience to wave their hands in the air, or to hug their neighbors, or to shake their hands, or to shout as loud as possible, for the purpose of triggering events full of surprises, something new that the participants are expecting from the interaction.

Further, the virtual interfaces of the private GUIs could be used for clandestine negotiations, but apart from the communications functionality, the virtual domain would still be unaware of the players' state of the diplomacy [10]. In such a constellation the system would allow different participants or even different groups of people to vote for different things or at different times. For example, users or groups would have to compete against each other or the interactive content would include role play characteristics. The system architecture would allow such scenarios since the server drives the voting mechanism and can handle dynamic menu contents even for different users at the same time.

In this paper we did not address service discovery, i.e. the user becoming aware and obtaining the external service or application (s) he is supposed to use. In our case the provider of the interactive art entertainment could advertise the service in its premises, together with instructions for downloading the application from a local Bluetooth service point or from an Internet page. Another technical issue we have yet to address is the scalability of the current implementation, which becomes relevant when we would like to include larger user groups.

We also did not discuss candidate business models. In our system users would have to pay for GPRS data when joining the voting. However, the amount of transferred control data is very small compared to e.g. browsing internet pages. We do not expect it to be a problem, however, as people are increasingly using data connection e.g. to browse the internet with their phone. Hence, they often pay a monthly fee for data access already. Further, mobile phones equipped with WLAN radios are starting to enter the market hence a pub could offer the proposed system as a free service in its WLAN hotspot.

5.2 DEVELOPING OTHER INTERACTIVE ART CONCEPTS WITH THE MOBILENIN ARCHITECTURE

The MobiLenin system is a combination of multimedia art (interactive music video), public display, mobile technology and a simple server. We briefly discuss few factors promoting the MobiLenin architecture as a good platform for developing other interactive art pieces.

1. EASE OF USE. Easy-to-use client applications on ubiquitous personal mobile phones are used for interacting with the art piece shown on a public display.

2. FLEXIBILITY. The server is controlled with simple scripts, which allow flexible tailoring of the application. Similarly, the Python scripts of the client application facilitate easy and flexible modification according to the application.

3. MODULARITY. Each component has well-defined interfaces and APIs. This allows for example replacing the current multi-track music video with versatile dynamic content whether it is a short movie with non-linear structure, a game or any other multimedia art.

4. REAL-TIME CONTROL OF CLIENTS WITH PRIVATE RETURN CHANNEL. The architecture allows real-time control of the client UI for the purpose of implementing well-defined dynamic HCI patterns for both individual users and groups. The private return channel allows the application to communicate privately with individual users, which can be utilized for various purposes.

6. NOTE

A video of the experiment described in Section 3 is available at http://www.leninsgodson.com/mobilenin/mobilenin_js_01.avi.

As soon as we have polished and packaged the source code for distribution, it will become available to the general public at the above mentioned website.

7. ACKNOWLEDGMENTS

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Article 2:

"Combining Web, Mobile Phones and Public Displays in Large-Scale: Manhattan Story Mashup"

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ABSTRACT

We present a large-scale pervasive game called Manhattan Story Mashup that melds together the Web, camera phones and a large public display. The game introduces a new form of interactive storytelling, which lets an unlimited number of players author stories in the Web while a large number of players illustrate the stories with camera phones. This paper presents the first deployment of the game, involving 184 simultaneous street players and a detailed analysis of quantitative and qualitative results. The analysis shows how the game succeeds in fostering players' creativity by exploiting ambiguity and how the players were engaged in a fast-paced competition, which resulted to 115 stories and 3142 photos in 1.5 hours. We present details on game implementation and set up which include practical lessons learnt about a large-scale experiment.

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1. INTRODUCTION

Manhattan Story Mashup (MSM) combines the web, mobile phones and one of the world's largest public displays in Times Square to a large-scale pervasive game. During the game, 184 players moved

around Midtown Manhattan shooting photos, which relate to words written by players in the web. Words were chosen from sentences, which together with newly taken photos formed illustrated stories. These stories were shown on the Reuters Sign in Times Square in real-time.

The game introduces a new form of interactive storytelling, which lets distant people to collaborate in real-time. The web players get a real-time human-mediated sneak peek to the physical world, which they may steer at a desired theme. The street players, who are taking the photos, may use their imagination at the fullest while trying to find the requested targets in a fast-paced competition. Since both the requested individual nouns and the returned photos are highly ambiguous in nature, the game feels somewhat mysterious, yet meaningful and exciting to all the players. On the web player's viewpoint, this may be seen as collaborative leisure [1] whereas the street player may see it as an urban game.

Manhattan Story Mashup melds together many concepts from earlier pervasive games. It links the physical and virtual worlds [2] and engages the players in a collaborative and competitive effort of storytelling [3]. It also entices players to share their experiences through a public display [4, 5]. and provides an entertaining and motivating context to produce experimental data for further purposes [6].

MSM is a part of the SensorPlanet project at Nokia Research Center. In its origins, it was motivated by the need to understand issues related to mobile phone-centric sensing. Especially we wanted to get hands on vast amounts of real-world data, collected by actual mobile phones. Design, implementation and orchestration of the game provided valuable knowledge on experimentation with a pervasive application in the real world.

The game produced a rich set of data. All game events were collected in a database, which allowed us to analyze the whole game event afterwards in detail. Immediately after the game, the street players were asked to fill in a questionnaire, which contained questions about the game design and experience. Analysis of both the quantitative and qualitative data is presented in section 5. Some of the design decisions proved to be remarkably successful; they are listed in the conclusions. We also outline the system implementation and the set up process, which present some practical lessons learnt.

2. PRIOR WORK

Locationing has been a defining feature in many earlier pervasive games. For instance, Pirates! [8] uses the physical world as a game board in which the game takes place. In this constrained game arena locations of the players may be determined using short range radio beacons. Yoshi [9] and Bill [10] exploit spotty coverage of WiFi networks in a clever way by taking advantage of this seeming limitation. In these games, the game play is designed around the concept of physical location. MSM was about to utilize locationing as well but only in a minor role. However we could not come up with a technically straightforward locationing method, which would have fitted in the game without taking too much attention from the key concepts. Despite of this, we logged internally the GSM cell IDs of the players during the game.

MSM is first and foremost an urban photo hunt with a twist. A similar concept, involving both camera phones and public displays, was sketched by PhotoPhone Environment [11], although they did not present any implementation. MSM and Snagu (http://snagu.com) share the common concept of ”reverse-Flickr”: Given a keyword or tag, the player takes a photo resembling the word. Sharing the Square [1] is a system for sharing leisure between distant people through photographs, voice and location. The MSM concept is tangential to the Square's idea of implementing co-presence through an interactive photographing process. Their treatise of shared photographing is relevant for MSM as well.

Manhattan Story Mashup builds on previous works of research, which combine the physical and the virtual into a seamless game experience. Two large-scale games were produced in collaboration between the artist group Blast Theory and the Mixed Reality Laboratory at the University of Nottingham. In Can You See Me Now [12] online players are chased through a virtual model by street players who play in a real urban environment. Similarly, Uncle Roy All Around You [7] involves players both in the field and in a parallel virtual world. Street players were given a task to search for a character named Uncle Roy. Remote players, together with professional performers, guided the street players in their quest. Experiences from

these games provide a solid background for designing and orchestrating collaboration in MSM.

Both the previous games are carefully orchestrated and controlled together with professional performers, which play a major role in these games. In contrast, our motivation was to gain understanding in spontaneous behavior of players, both in the Web and in the streets. Therefore we deliberately left room for emergent features and unexpected events to happen. Furthermore we designed MSM so that there would not be any inherent limitations in number of participating players. This sets MSM apart from many previous games; for example Can You See Me Now can be played only by fifteen online players at time. We hypothesize that this approach might give us realistic data on real-world sensing and user behavior, which may be generalizable to non-game related settings as well. The approach is akin to some previous games for collecting "serious" data, such as the ESP game for labeling images in the web [6].

As an example of interactive storytelling on mobile devices, Bamford et al. [3] reported an innovative mobile game in the form a multi-authored mobile book based on the 1920s surrealist technique of Exquisite Corpse. The book builds from a series of standard text message length contributions, each author being given only the previous message on which to base their own contribution. MSM goes a step further by including the images illustrated by some people and stories written or mashed up by other people, using recent techniques of the social web.

The usage of public displays haven been researched in various contexts. One of the main challenges associated with interactive public displays is how to entice people to interact with them [4]. Another challenge is how to share a single public display between multiple users. This is where personal mobile phones come handy in terms of dispersing access and control. For example, Scheible and Ojala [5] demonstrated with MobiLenin a solution for realizing multi-user interaction with a public display using personal mobile phones.

3. GAME DESIGN

The overall goal from the perspective of a mobile player in MSM is to collect points by shooting photos for illustrating stories written

by people in the web. The player who collects the most points is the winner of the game. There are two tasks for the mobile player: One task is to shoot photos representing nouns that are extracted from story sentences created by people on the game's website in real-time. The mobile phone receives these nouns automatically and shows them as keywords in a list on the screen and the player just needs to select a keyword.

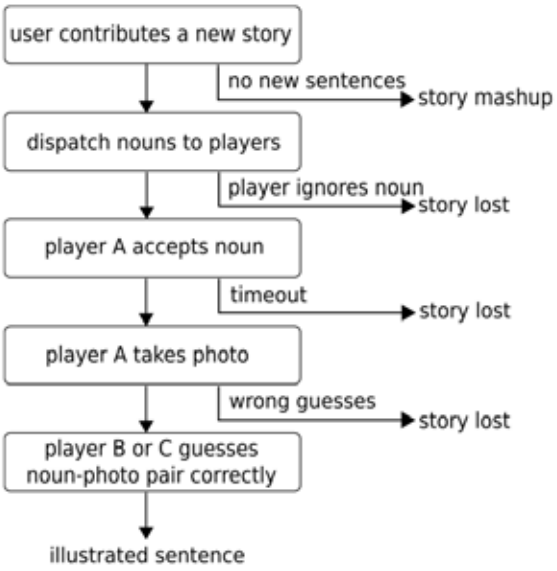

Fig. 1. Gameplay

The phone camera will then open automatically and start a countdown timer that grants between 60-90 seconds time to shoot the photo. The photo is then sent automatically to the game server. The other task is to match keywords to images taken by other players to validate the quality of the images going into the system. The screen will show an image and a list of four keywords including the correct one. The player needs to guess which of the keywords matches the image. The image is sent at the same time to another player for guessing in order to let the players compete. The first player to guess the word-photo pair correctly gets the points.

The player can gain different amounts of points: 1 point for shooting a photo, 6 points for guessing correctly, 9 points for a photo that is taken by the player himself and correctly guessed by some other

player. The points are accumulated during the whole game. The players were able to see their own score and rank all the time on the lower part of the phone screen.

The core of the game is to produce imaginative noun-photo pairs. The rationale for guessing is to make sure that the photos actually represent the desired target, or that the association between word and photo is conceivable by another human being, even though it may be highly ambiguous. The reason for having two players to guess the same photo is simply to increase likelihood of having a successful guess and to motivate each player to guess well – otherwise a competitor would gain more points.

The gameplay is illustrated in Fig. 1. If a storyteller in the web chooses to use only already illustrated sentences by other people, no mobile player actions are needed. If the storyteller contributes new sentences, a noun from each sentence must go through the illustration process. If the mobile players fail to accomplish any step, the story will not finish since at least one sentence will be left unillustrated.

In case that the web players are unable to keep the mobile players busy by writing enough stories, there is a backup mechanism, which dispatches nouns to the mobile players from a predefined list. If such an automatically dispatched noun passes the illustration process, it may be used in a new sentence without additional delay.

3.1 DISCUSSION

Based on their experiences with Uncle Roy All Around You, Benford et al present a design framework for mobile experiences [7]. In the following, we reflect main points of our design to this framework.
We wanted to avoid the situation in which the web players would be mere spectators, while the street players would be the de facto performers. Games like Uncle Roy and Can You See Me Now provide the remote player a virtual model of the physical city, thus mimicking the physical experience to some degree. In contrast to this approach, our design provides two different, yet equally important facets to the

game, both respecting the natural context of action: The web player feels that she is participating in a Web 2.0-ish collaborative effort, so she may well regard herself as a major performer in the game. In parallel, the street player takes part in the hectic urban game, which makes her another true performer. This two-sided approach is akin to so called seamful design [10] of ubiquitous systems. Instead of trying to hide differences between the virtual and physical worlds, we try to exploit the best features of both worlds.

However, both players are also spectators. Following the taxonomy presented in [13], we consider the street player to have a suspenseful view to the game, since she is unable to see the effects of her actions immediately: She takes a photo and hopes that someone guesses it correctly and it will get integrated to a story. In the web player's point of view, the game is magical, since she cannot identify the exact source of the photos: She sees newly illustrated sentences, written by other web players popping up every now and then and her own sentences becoming illustrated by some random street players.

The large public display supports the suspenseful and magical nature of the game. After some delay the street player may see her own images on the display as a part of a story. The web players could see their stories through the Reuters' webcam magically presented in a physical place in some distant location. Another important feature in our design is deliberate ambiguity in the tasks. This approach is suggested for game design in [7] and [14]. Instead of forcing or encouraging the web players to use only unambiguous and concrete words, such as "house", "milk" or "sun", we picked a random noun from each sentence. This made the game more exciting and left plenty of room for players' creativity. Ambiguity is especially apparent in the guessing part of the game, which requires a human player to interpret photos: Consider an image of a building. Is it a hospital or a dormitory? All these tasks boil down to being able to guess another player's intent, even though the message is mediated through an ambiguous channel, namely through a word or a photo [14]. It is even desirable that some ambiguity remains in the resulting stories since the result are often hilarious.

4. IMPLEMENTATION

4.1 STORYTELLING TOOL

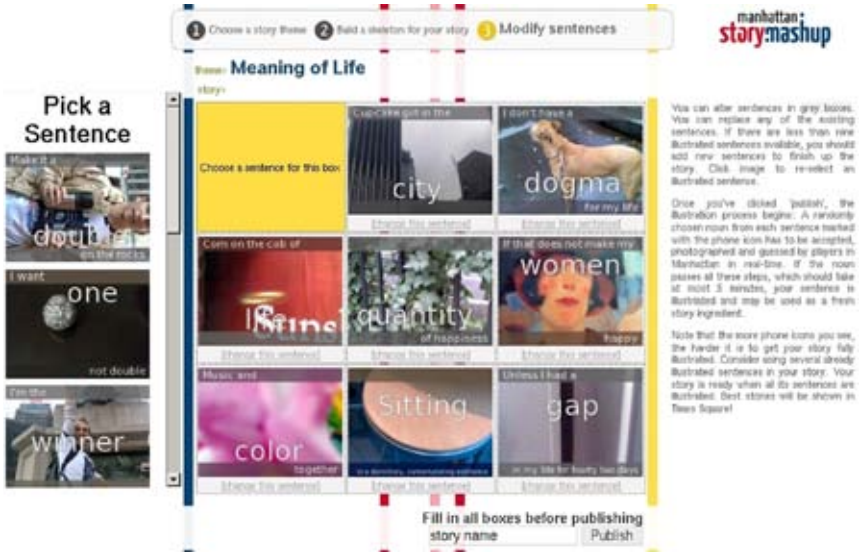

Fig. 2. Storytelling tool in the web

The Storytelling tool lets an individual web site visitor to leave her creative handprint to a large public sign, as well as interact with the real people in the streets of Manhattan. However presenting just a collection of individual contributions would be rather uninteresting. Also the required effort to make an individual contribution from the scratch might be prohibitively high for many. Instead, the storytelling tool lets the user pick a previously contributed story and use it as a basis for her own story. Alternatively one can use previous sentences to mash up or remix a personal story.

To enhance usability and approachability, the first steps with the tool were made as convenient as possible. No registration was needed: There was a link in the front page leading directly to the tool. There were no options from which to choose. The user could start playing around with the tool immediately and she could contribute her own sentences with no restrictions.

A story consists of nine illustrated sentences as shown in Fig. 2. For each cell or slot the user may either pick an already illustrated sentence, written by someone else, or she may write a new sentence. Once

the user has chosen appropriate content for each slot and the resulting story looks somewhat meaningful, she may publish the story.

It is practically impossible to detect dubious or nonsensical sentences automatically as the problem is highly semantic in nature. However, we performed some simple filtering using a blacklist of 333 common profanities. We also made some syntactical checks, ensuring that the sentences are long enough and do not contain any meaningless characters.

After publishing, each new sentence is tokenized. Each token is checked against WordNet [15] and nouns are collected. From each new sentence a random noun is chosen for illustration. The nouns, the number of which may vary from zero to nine, are dispatched to random players in Manhattan, yet taking care that no player has more than ten nouns at time. After this the story moves to the pool of incomplete stories, until all its sentences are illustrated. For an overall view to the gameplay, see Fig. 1.

Storytelling tool has an important feature that should keep the stories meaningful, even though users are free to write anything to sentences: When the user picks sentences for her story, she is presented a list of available illustrated sentences to choose from. This list is ordered by descending popularity: The more frequently a sentence gets picked, the higher ranking it will have in the list. This feature is similar to filtering mechanisms found in many social bookmarking sites, such as Digg (http://digg.com) or Reddit (http://reddit.com). The rationale is that even though someone may find entertaining to input nonsense to the system, almost no one regards nonsense written by an unknown person interesting. Thus nonsense gets disregarded by many and its ranking drops. This phenomenon is further amplified by the fact that most users consider only the top entries in the list, being too lazy to browse everything through, and thus increase the popularity of the already popular items.

4.2 MOBILE CLIENT

We decided to use Nokia N80 mobile phones in the game, mainly due to their new S60 3rd edition software platform, WiFi support and high-quality 3-megapixel camera. The game client software was implemented in Python for S60 (PyS60), which is an open-source

port of the Python programming language to the S60 platform [16]. Python was chosen due to its suitability to rapid prototyping and easy extendibility in native C++. As described below, source code availability was an important factor as well.

We implemented a set of custom UI widgets for the game instead of using the standard UI library. This gave us more flexibility in usability design and made the client look and feel more game-like. The standard PyS60 distribution includes support for taking photos, but does not provide the viewfinder. Since smooth camera usage is central to the game experience, we implemented viewfinder support as an extension. Thus the player did not have to use any other phone functionality or software besides our game client, which greatly enhanced game immersiveness.

Fig. 3. Mobile Client: Keyword selection mode, shooting mode, player statistics and gallery views

The game client has three modes: Keyword selection mode, shooting mode and guessing mode. The game leads the player from one mode to another. In the keyword selection mode player chooses one of the available nouns as the next target for shooting. The keyword choice activates the shooting mode, which opens the viewfinder and lets

the player to find a suitable target. Once the photo is taken, it is sent automatically to the server and the player returns to the keyword selection mode.

The game client polls the server every five seconds to update the list of keywords and retrieves requests for guessing. Once a new request for guessing is received, the guessing mode is activated automatically unless the player is shooting photo. In the guessing mode the player is presented four alternative nouns, one of which is the correct one, together with a photo taken by another player. After choosing one of the alternatives, the player is taken back to the keyword selection mode.

In each of the modes, there is a visible countdown timer, which forces the player to make quick decisions. In the selection mode, the timer expires keywords, which have been shown for over 90 seconds. In the guessing and shooting modes, the player is taken back to the selection mode if she was unable to act in 60 seconds. In technical point of view, tight timeouts make sure that players get a constant stream of fresh tasks and passive players cannot stall the game dynamics. Rather surprisingly, since players see that the game keeps going without their explicit action, they feel motivated or even urged to act. This was a major factor in making the game highly engaging.

In addition to the three main modes, there is a screen showing current player statistics. A simple gallery is provided so that the player could see the most recent photos taken by other players. These features were added to increase feeling of competitiveness and collaborative effort. In practice however, the single line in the keyword selection mode showing the player's current score and ranking in real-time proved to be sufficient for this purpose.

An important detail in large-scale field experiments involving mobile phones is how to set up a large number of devices. Installing software to 200 phones manually is not impossible, but it is a remarkable feat. There are some standardized methods for large-scale software deployment for mobile handsets, such as Over-The-Air Programming, but often these methods are only available for operators and phone manufacturers.

Our approach was twofold: First, we were able to compile a customized version of Python for S60 since its source code is freely available. We modified the user interface of the interpreter to include

functions for game client update and launch. Also the viewfinder extension was included in the new build. This reduced the number of packages, which needed to be installed. Secondly, we were able to automatize the installation process to some degree by using freely available Obexftp (http://openobex.triq.net) tool for Linux to transfer the installation packages to phones. We considered using several Bluetooth dongles to transfer packages to multiple phones simultaneously, but this proved to be somewhat unreliable in Linux. Instead, we used a USB-hub to connect five phones to a laptop at the same time, which greatly reduced time needed to transfer the files. After one has figured out the process, we can estimate that installing packages to some 200 phones would take 10-15 person hours. However other tasks, such as sorting out the SIM cards and recharging the phones, took two days from three persons.

4.3 LARGE PUBLIC DISPLAY

We rented the Reuters Sign (http://www.timessquare2.com) in Times Square for exclusive use during the game. The display system consists of 11 individual displays, which may be used either separately or as a single large display. This display was chosen due to its prominent location and enormous visibility. Times Square is an iconic location in global scale, thus the possibility to create personal content to be shown there was attractive for people around the world. Considering the storytelling tool, it was crucial that the web users could relate to the place where the stories were to be shown, even though the location was distant.

Once all the nine sentences of a story had successfully gone through the illustration process, depicted in Fig. 1, the story became a candidate for presentation on the display. We had a human moderator filtering the candidate stories using a separate moderation interface in the web. The interface allowed the moderator to “bless” a story for presentation, or to blacklist individual sentences containing unwanted content.

Once a story was blessed, it was automatically sent to the display system by the gameserver. Depending on the display status, the new story was shown there after some 1-5 minute delay. All the nine illustrated sentences were shown at once on the display. One by one, each

Fig. 4. The Reuters Sign in Times Square. Photos by Kitty Kat, Jürgen Scheible and snipp.

sentence was enlarged and shown on the large middle display for six seconds, as seen in Fig. 4.

The display added a unique twist and a big wow-effect to the game. It provided a feedback channel for the street players who were able to follow in real-time how their photos were interwoven into various stories. This role, providing a shared view to the game, was probably the most important feature of the display. In addition, the unique opportunity of getting a personal fingerprint to Times Square motivated both the web and the street players to produce imaginative content.

5. EXPERIENCE

The actual game event took place on September 23rd 2006 between noon and 1:30pm in Midtown Manhattan. The game was one of the featured games in Come Out and Play street games festival (http://comeoutandplay.org). We had invited 140 university students to participate from New York University, Parsons The New School for Design and Brooklyn Polytechnic. In addition we had invited some 70 persons from various companies and institutions to join the game.
In total 184 players played the game. During the game the players took 3142 photos and made 4529 guesses, 2194 (48.4%) of which were correct. Technically, there should have been 6284 guesses in total, assuming that every photo was guessed by two separate players. However, if all the players were busy, i.e. taking a photo or already guessing, only one guesser would suffice. In the extreme case that no guessers were available, the image was accepted as such. Also if the guessing timed out or the player closed the client without guessing, no guess was recorded.

Figure 5 visualizes the whole gameplay. Each row in the graph corresponds to a player. Rows are ordered by descending score, thus the topmost row corresponds to the winner of the game. X-axis is time, from the game start to the end, 4902 seconds or 81 minutes in total. Color segments indicate player action at every moment, which correspond to the three modes of the game client: White indicates keyword selection mode, green shooting and blue guessing.

The most distinctive feature in the graph is the large gap in the middle. This corresponds to an unknown bug, which appeared af-

ter the game had been running for some 30 minutes. Game server stopped dispatching nouns, apparently assuming that all players already have the maximum amount of pending keywords. It took a while to notice that the bug affected all the players. After this, the game server was restarted and the game history was re-evaluated, which normalized the situation and the game continued.

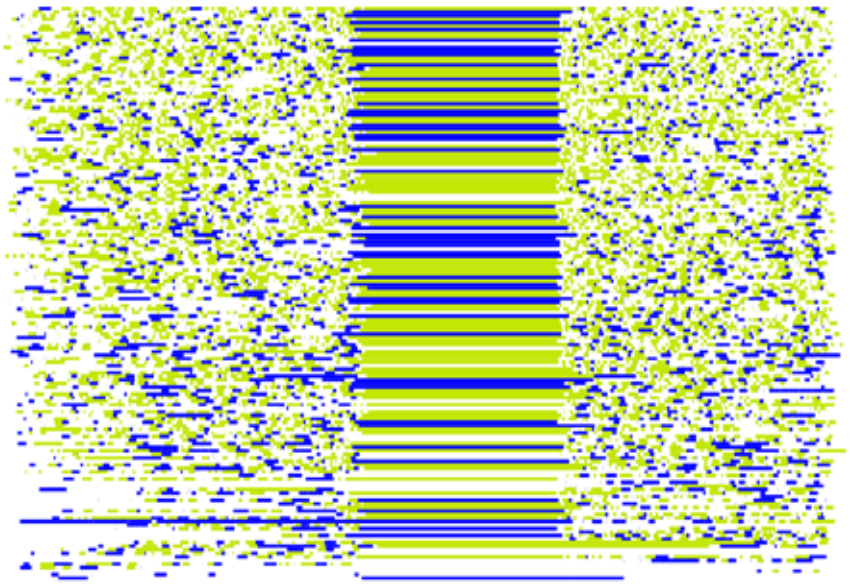

Fig. 5. Gameplay visualized: Rows correspond to players, x-axis is time. Green segments denote time spent taking photo and blue segments denote guessing. Rows are ordered by descending score.

The following phenomena can be interpreted from the graph:

1. Gameplay was fair: All the players seem to have done comparable amount of shooting (green) and guessing (blue).
2. Nouns were not too hard: There are only few long white gaps in player actions, thus players accepted proposed nouns quickly.
3. Players were motivated: Even the bottommost players played hard all the time.
4. Players did not get bored: Right-hand side of the graph looks the same as the left.
5. Scoring is not random: Segments are slightly longer in the bottom part of the graph, indicating that low scores correlate with slow actions.

Observation 1. proves that the game dynamics worked correctly: It was a deliberate decision that a player could not avoid guessing by staying in the shooting mode all the time. **Observation 2.** proves a hypothesis correct: Players were remarkably creative with the words and they were able to illustrate even the most abstract words, such as "synergy", by utilizing the rich urban environment and spontaneous acting. **Observation 3.** was unexpected: We assumed that the players who notice their ranking to be rather low, say 83th, would soon lose interest in playing. However it seems that the players often got spurts of easy targets, leading to sudden increase in ranking which kept motivation high. This leads to the conclusion that showing the current ranking in the game UI is a good idea. Similarly **observation 4.** was unexpected: We decided to make the game short enough, so that people would not get bored during the game. Clearly the game was engaging enough to keep players fully focused for 90 minutes. **Observation 5.** was expected, but we assumed that the effect would be much stronger. The data shows that the players were surprisingly homogeneous, regardless of their final score.

Table 1. Gameplay statistics over players

Variable	Min	Max	Median
Nouns chosen	2	64	35
Photos shot	2	58	32
Guesses	3	56	28
Correct guesses	1	29	14
Score	18	430	246
Guessing time (avr secs.)	6.5	39.3	15.0
Shooting time (avr secs.)	15.9	91.9	33.4
GSM cells visited	1	26	14

We analyzed the game history also quantitatively, to confirm the observations from the graph and to find hidden patterns. Basic statistics over players are presented in Table 1. Player characteristics were distributed rather uniformly and no clusters of different types of players were found, which agrees with observation 3. Overall, it seems that that the players were a homogeneous group of well-motivated individuals, which resulted to a uniform outcome. This provides us a solid baseline of the game design against which differ-

ent, more heterogeneous groups of players may be evaluated in the future.

We were interested in finding out whether the winning players had some special characteristics compared to the others. We found no clear pattern related to number of correct guesses or guessing in general. The most remarkable correlation exists, not surprisingly, between the average shooting time and the final score. To conclude, it seems that the winners won by making good decisions quickly and by acting fast. This might be considered as a positive outcome for a new game design.

We also recorded player locations based on GSM Cell IDs. Even though the game took place in a restricted area, namely between the 59th and 43rd streets, around the 5th Avenue and Broadway, in total 197 unique cell IDs were recorded. There seems to exist a weak positive correlation between the number of cells visited and the final score.

5.1 PHOTOS

The most intriguing tangible result of the game were the 3142 noun-photo pairs. The game was designed to stimulate creativity. Our research motivation for this was to get some preliminary ideas on what kind of "action possibilities" urban environments might provide and what kind of non-trivial features people are able to find in their surroundings.

We analyzed 523 photos manually, to gain understanding in the types of associations present in the photos. The largest single theme was 193 photos showing human beings, or players in our case. Sometimes acting was used to set out a role, facial expression or a character, as in the leftmost photo in Fig. 6. However, the photos did not always depict a human being as such, but another player acting out an abstract concept such as "evidence", "link" or "equal" as seen in the middle photo. Sometimes the association was related to the textual form of the word, resembling a wordplay, as in the rightmost photo.

We were surprised to see how effortlessly the players were able to cross the boundaries of ordinary public behavior, e.g. by acting out publicly, once they started to look at the world through the game client, especially when playing in a team. This suggests that concerns

related to blurring the line between the virtual and physical, which are discussed e.g. in [7], are valid even though the game by itself may be quite harmless and abstract, as in our case.

Fig. 6. Example photos and sentences

Another imaginative approach to deal with abstract concepts was to deliberately blur or shake the photo to hide irrelevant details. Of the analyzed photos, 155 were shaky. Shaky photos were also used to depict colors or movement, as in "explosion" and "speed" or kicking something to show "temper". In case of unambiguous but unavailable objects, such as "mustard", "film" or "balloon", players tried to blur another object with some resemblance to the target object to produce the desired effect. Naturally some photos were shaken or out of focus by accident. This happened often with close ups ("powder", "ear", "bruise") if the player forgot to switch the macro mode on. Since the players were forbidden to use any visible trademarks or copyrighted items in the photos, some players tried to blur the offending target to circumvent the rule.

Since the nouns were recognized using WordNet, which also includes semantic relations between words, we were able to group nouns under some generic categories or themes automatically. To reduce the number of categories shown, Table 2 presents only those categories or hypernyms, which were used to extract words for automatic dispatching before the game. The numbers in parentheses indicate the total amount of nouns illustrated in the corresponding category. Accuracy indicates the percentage of correctly guessed noun-photo pairs in the category.

It is worth noting that the lowest accuracy is well above the default, 0.44, which is the probability that at least one of the two guessers makes the correct choice assuming that the choices are random. Since the actual accuracies are above this, we can assume that the

players were paying attention to the guessing part and probably tried to perform as well as possible.

Table 2 shows that explicit human-related subjects, such as facial expressions or characters, are easy to act out and photograph regardless of the surroundings. Likewise unambiguous concrete objects, such as bodies of water, shops, and beverages are easy to guess. In contrast, objects that are difficult to set out, such as “dormitory” or “breakfast”, produce often ambiguous photos. However, the players seemed to enjoy ambiguity and in some cases they deliberately took ambiguous photos for the sake of fun and ingenuity. Thus although ambiguous words and photos made the game more difficult, they were likely to provoke engagement and exploration in the game [13].

Table 2. Guessing accuracies per WordNet categories. Total number of guesses in parentheses.

Hypernym	Accuracy	Hypernym	Accuracy	Hypernym	Accuracy
facial expression	0.94 (17)	car	0.74 (34)	currency	0.67 (3)
character	0.86 (7)	show	0.72 (25)	friend	0.66 (35)
writing implement	0.85 (13)	bread	0.71 (14)	edible fruit	0.64 (28)
body of water	0.84 (31)	wheeled vehicle	0.69 (36)	light	0.64 (67)
athlete	0.83 (24)	waste	0.69 (29)	road	0.62 (29)
shop	0.81 (26)	motor vehicle	0.68 (19)	toy	0.61 (18)
performer	0.77 (22)	tool	0.68 (50)	material	0.61 (79)
chromatic color	0.77 (61)	human	0.68 (499)	piece of work	0.59 (22)
beverage	0.75 (24)	garment	0.68 (87)	dish	0.56 (48)
figure	0.74 (72)	device	0.67 (181)	building	0.56 (70)

5.2 WEB

Approximately 4000 unique IP addresses had visited the game web site at storymashup.org before the game launch. The storytelling tool was open only during the game for 90 minutes. During this time 165 unique IP addresses visited the game web site. 115 stories were published, which were mashed up using the 271 sentences written during the game.

Since the players in Manhattan accepted 5603 nouns in total, only 4% of the words originated from the new sentences. However, the storytelling tool offered a possibility to use already illustrated nouns in a sentence. This feature was used 129 times. We hand-picked 26 best stories which were shown in Times Square. The game design,

as well as the implementation, would have been able to handle much larger number of storywriters in the Web.

A major technical research motivation for having the web site in the first place was to gain better understanding in different time-scales of the web and the physical world, and how it affects the system dynamics. In practical terms, minutes make a big difference while one is standing on a busy street in Manhattan, compared to web site which is still mostly conceived as a rather static entity. Especially it is not customary to have a web site open only for 90 minutes, even though such a happening makes sense in the physical world. Thus to achieve smooth real-time interaction between the web and the physical world, the system must carefully take into account inherent differences between the two time-scales.

Correspondingly, the difference in the user base between the web and mobile devices may be huge, yet it is not easily predictable – another lesson learned. Being able to accommodate highly volatile user bases is a challenge to the system dynamics. In our case, for example, the system should not have discarded stories so eagerly (see Fig. 1), having so few storytellers. However, the design was based on the assumption that there are far more web users than players in the field, and thus the stories should have been in abundance. In the future we are determined to increase the system flexibility to adapt to situations like this.

The web site included a questionnaire, which was answered by eight web players. Apparently the players who answered the questionnaire had generally enjoyed the experience, so it is difficult to make any conclusive remarks. To exemplify nature of the results, we include here answers for three of the questions:

Any surprise elements? "yes, when it became possible to be funny and make connections ... very surreal", "Yes, when I saw the image that was for the words I selected.", "discovering own sentences in other stories was very surprising.", "It was a surprise that "the game" didn't seem to work at all. Also the term "game" is misleading. It is more comparable to a mobile entertainment solution. Not into a game, as you don't play it anyway." **What did you like most?** "crafting the story and wondering what photos would come out using my knowledge of the city to make puns", "Seeing everyone else's creative efforts.", "How people used my story und how the pics where done to

my keywords.". **Do you want to play this game again?** "Now that I have the hang of it, I'm thinking of new ways to play it...", "yes! all the time", "Yes. I would like to master what I don't understand", "Yes, please!!!!! It could lead to addiction, cause it is so much fun to write stories to the topics you offered and to wait how they will develop.", "No, as it is not a game. If it'd work, I would reconsider writing in there".

5.3 QUESTIONNAIRE

Qualitative data reflecting the user experience was evaluated with a questionnaire, which was collected immediately after the experiment. The questionnaire contained 26 statements on which the users were asked to answer on a 5-point scale between 1 (disagree completely) and 5 (agree completely). In addition there were 23 open-ended questions. A few individual users and 2-3 groups of users were also video-interviewed after the experiment. Observation was carried out during the experiment with a video camera.

Of 184 players who participated the game, 99 returned a filled in questionnaire (56 males and 43 females). The age distribution was as follows: 24 players of age 18-24, 64 of age 25-34, and 15 of age 35+. Each player got an invitation to the Story Mashup evening party upon returning the questionnaire. In the following, we adopt the following notation for brevity: "Statement" (X), where X denotes the average of responses of 99 players on the 1-5 point scale.

As a general observation it was very clear that people really enjoyed playing the game: "It was fun and engaging to play this game" (4.07). This underlines that creating an interactive, engaging experience is key for successful user participation for any large-scale research experiment.

Of all the questions, it was a surprise that exactly the two major tasks that mobile players had to perform, got the highest rating: "I enjoyed hunting for photos" (4.63) and "I enjoyed the guessing part of the game" (4.39). This can be seen as a strong success from the game design point of view. It shows that players made an intellectual and emotional investment, which Ryan [17] claims to be a precondition of an interactive medium to open its world to the user. Clearly, the use of mobile device as an interaction device and as an image

capturing device in the context of our game is strong: "When I was holding the phone, I felt confident hunting for images and doing the guessing part" (4.18).

It seems that hunting for points and competing with other players in game context indeed provides a motivated activity. We can see from the data that the game mechanisms played a major role in getting players engaged and motivated. The ratings are very high: "I like the competitive style of play" (4,32) and "I was motivated by the scoring mechanism" (4,25).

People were very active and also various interactions between people took place, which can be easily seen in the photos as well (see Section 5.1). People enjoyed socializing and team play: "I did prefer to play this game alone rather than joining a team of other players" (1.43). Players also felt, with some variation, that they are part of a joint authorship: In this case it was by contributing images to the web stories and ultimately to the large public display: "While playing I felt I was part of a joint activity between players on the web and mobile players in Manhattan" (3.22), "I felt I belonged to a joint, collaborative action contributing to a common goal" (3.59) and "For me it was an important part of this game to see the illustrated stories at the public display at Times Square (3.28)".

Also the usability goals were met, meaning that the system should be efficient to use, easy to learn and easy to remember: "The mobile application was easy to use" (3.19), "It was easy to understand the game concept" (4.21) and "At any given moment it was clear to me what I was supposed to do" (3.51).

6. CONCLUSIONS

The game was a greater success than we expected. The game design proved to be engaging which supports our core design decisions. We were delighted by the amount of imaginative photos taken during the game. On the other hand the game was almost too motivating, since the data turned out to be quite homogenous, although we expected that some of the players would play rather lazily.

We think that the following factors contributed the most to the success of MSM: Lazy Shooting: A user with a camera is a powerful way to collect interesting data from the physical world. In addition,

in our case it was effortless: The camera activated and sent the image automatically. This encouraged players to shoot many photos. Ambiguity: Players felt that clever and imaginative thinking contributed to their ranking. Players spent most of their time doing something that is natural to human beings: Trying to infer other people's intentions or trying to infer how other people would infer my intentions. Teamplay: Players formed teams spontaneously and used them to act out difficult words. Teamplay also lowered barrier for crossing the boundaries of public behavior. Speed: The game felt immersive since the players did not have time to think about anything else. Since the players' ranking was updated all the time, even a short pause resulted in a noticeable drop in score. Integrated Game-Flow: A single simple game client was used to play the game. Even the camera was included in the client. This ensured that we were able to streamline the UI to the bare minimum. With rapid prototyping tools like Python for S60, one does not have to accept suboptimal interfaces.

On the other hand, we could not find satisfying answers to the following issues: Time and Web: Even though technically our web site worked as expected, we would have expected more web players participating in the game. We assume that a major reason for the smallish number of visitors was that the game interface was open only during the game, for some 1.5 hours. In the future, we have to pay more attention to matching the physical and the virtual time-scales. Scalability: Organizing a game involving almost 200 physical players was a major feat. The semi-manual approach for installing the phones does not scale easily to even larger settings. Duration: The game lasted for 1.5 hours which is enough for an intensive game but in order to get more data, we would like to keep the system running for a longer period of time. Adaptability: If the game involves web or it is otherwise open for anyone to participate, the rules should adapt to varying number of players and activity. This is especially important if the game runs for a longer period of time. Many of the previous issues relate to the natural friction between the web and the physical world. It is clear that further experiments are needed to find best practices and design frameworks for successful interaction between the two worlds.

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Article 3:

"Story Mashup: Design and Evaluation of Novel Interactive Storytelling Game for Mobile and Web Users"

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ABSTRACT

This paper studies the design rationale and evaluation of an urban storytelling game called Story Mashup. In the game ubiquitous computing infrastructure is utilized to facilitate real-time interaction between mobile and web users. Textual stories written in the web by certain people are illustrated by other people taking matching photos with camera phones. Complete stories are then displayed on a large public display and on the web. To carry out a thorough empirical evaluation of the game design in a real world setting, the game was played in New York in September 2006 with 180 players and by people in the internet around the world. The results show that the adopted iterative design process succeeded in achieving the goals set for usability, user experience and game stimulation.

CATEGORIES AND SUBJECT DESCRIPTORS

H.5.1 **[Information Interfaces and Presentation]:** Multimedia Information Systems – *evaluation and methodology, video*. H.5.2 **[Information Interfaces and Presentation]:** User Interfaces – *evaluation and methodology, input devices and strategies, interaction styles.* H.5.3 **[Information Interfaces and Presentation]:** Group and Organization Interfaces - collaborative *computing, computer-supported cooperative work, evaluation and methodology.*

GENERAL TERMS
Design, Experimentation, Human Factors.

KEYWORDS
Multimedia art, hybrid interfaces, experimental evaluation.

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1. INTRODUCTION

The Story Mashup system introduces a new form of interactive storytelling by mobile and web users, realized as an urban game. The system uses ubiquitous computing infrastructure to dynamically combine the respective virtual and physical spaces of a web user and a mobile user into a multimedia game. The game is expected to trigger people's creativity into generating unpredictable and spontaneous visual stories in a collaborative manner.

We have previously reported the technical implementation and the overall game design of the Story Mashup [12]. The novel contribution of this paper lies in reporting the design rationale, the iterative design process employed in the development of the Story Mashup system and the major design decisions taken. In the following we provide an in-depth analysis of the various design stages and their design outcomes when building a series of prototypes. Further, we report new, previously unpublished findings on the empirical evaluation of the final system, and contrast them with the design rationale, providing valuable lessons learned for the community.

In Story Mashup, individual keywords of textual stories written by web users are presented, one word at a time, to mobile users for the purpose of taking a matching photo with their camera phone. Each

resulting keyword-photo pair is validated by presenting the photo together with the original keyword and three other words to two other mobile users, who are asked to choose the most appropriate word given the photo. If either of the two chooses the original keyword, the photo is approved into the resulting visual story. All resulting stories are displayed on the web and selected best ones on a large public display. The players are awarded points for taking photos and for choosing the original keyword.

The Story Mashup system comprises of three physical building blocks: camera phones equipped with the game client, a website in form of a storytelling tool and a large public display. The fourth interesting functional component is the "human computing" carried out by mobile peers for the purpose of validating the photo offered for visualizing a particular keyword in a story.

When designing interactive systems and games it is useful to use guidelines and heuristics as part of the design process. Various people have studied this. Desurvire *et al.* [3] introduced Heuristic Evaluation for Playability (HEP), a comprehensive set of heuristics for playability. They say that in the realm of game playability, there is a need to go beyond basic interface game usability evaluation to assess additional properties of the game experience including game play, story, and mechanics.

Sweetser and Wyeth [11] have been looking into enjoyment in games and introduced GameFlow, a model for evaluating player's enjoyment in games. It consists of eight elements – concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. Each element includes a set of criteria for achieving enjoyment in games. Malone [6] constructed a list of heuristics for instructional games.

Nielsen has introduced his usability heuristics [7]. Preece *et al.* [8] have explained that different combinations and types of heuristics are needed to evaluate different types of applications and interactive products.

The Story Mashup system deliberately promotes ambiguity in the gameplay, in order to leave room for the players' own creativity. Various benefits of ambiguity in design are discussed by Aoki and Woodruff [1]. We also discussed the dual role of the player in Story Mashup [12], the spectator versus the performer, in the light of the various aspects of the spectator experience explained by Reeves et al. [9].

In this paper we focus on the design and evaluation of the Story Mashup system. Our major goal from a design point of view was to build a system that a) provides engaging experiences to players, b) triggers creativity in writing stories and taking photos, and c) fosters collaboration and social interaction in form of team play. We believe the usability of the system plays a crucial role in achieving these goals. We were interested to see whether a novel system as Story Mashup could reach these goals by following well known design processes that include prototyping, iterative design, lab tests and empirical evaluations in the true environment of use.

This paper is organized as follows. Section 2 describes briefly the overall game design. Section 3 provides an in-depth analysis of the various design stages and design decisions regarding prototype design and evaluation. Section 4 presents the findings and lessons learned. Section 5 summarizes our thoughts.

2. GAME DESIGN

The game involves three different parties: a) the web players in the internet using the storytelling tool to contribute stories, b) the mobile players hunting for photos and c) the large public display showing the resulting illustrated stories (Fig. 1).

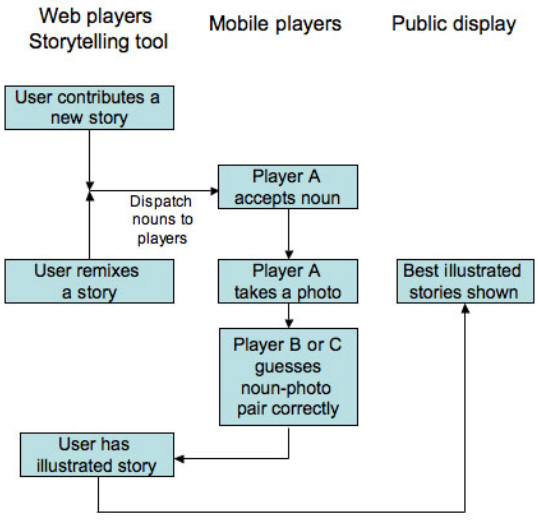


Figure 1. Game flow.

A web player writes a story with the storytelling tool in the Internet. After that the Story Mashup system extracts one noun of each sentence of the story, which are dispatched to mobile players. The mobile player A is provided with a list of up to 10 nouns. After accepting a noun (s)he has 90 seconds to take a photo matching the noun. After that the photo and the noun are sent together with three other nouns to mobile players B and C, who are asked to pick the noun matching the photo. If either B or C picks the original noun, the photo is sent back to the web player illustrating the story. The illustrated stories end up in a story pool, of which selected stories are displayed on the public display. A web player can also remix stories by choosing sentences from the story pool of already illustrated stories and adding her/his own new sentences into it, in order to get a new illustration in the same way as with a new story.

The **mobile client** has different viewing modes (Fig. 2). The keyword selection mode for choosing incoming nouns as the next target for shooting; The shooting mode that opens the viewfinder and starts a 90 seconds timer; The guessing mode which presents a photo taken and four alternative nouns, one of which is the correct one; The player statistics mode for showing current player statistics; The gallery mode to see photos taken by other players.

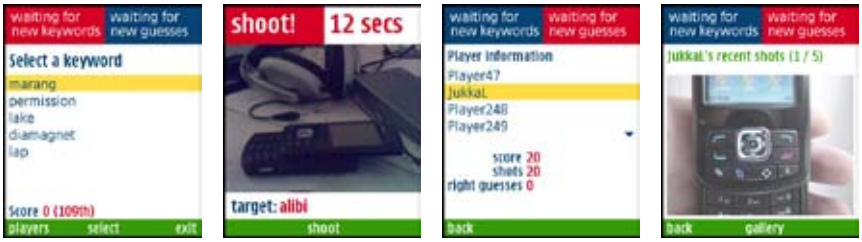
The **storytelling tool** allows a web user to write stories from scratch or pick a previously contributed story as a basis for an own story. The tool allows leaving a creative handprint onto a large public display and interacting with real people in the streets.

The **public display** shows a selection of the illustrated stories, providing the storywriters and photo hunters an opportunity to display their collaborative work in form of street art.

3. DESIGN RATIONALE

Recalling our design goals of a) providing engaging experiences to players b) triggering creativity in writing stories and taking photos c) fostering collaboration and social interaction in form of team play, and the role of high usability and successful interaction design in achieving these goals, we first briefly describe the design guidelines, heuristics, and processes chosen for this work, of the many potential

candidates. Then we provide a detailed description of their application in the design of the Story Mashup system.



(a) (b) (c) (d)

Figure 2. Screenshots of the mobile clients' viewing modes: (a) keyword selection; (b) shooting mode; (c) player statistics; (d) gallery.

3.1 DESIGN GUIDELINES AND HEURISTICS

Preece *et al.* [8] point out that the role of evaluation is to make sure that understanding of the users' needs happens during all stages of the development. They explain that different combinations and types of heuristics are needed to evaluate different types of applications and interactive products. To meet our challenge of designing both the mobile client and the storytelling tool with high usability, we decided to employ commonly known design practises, identify different types of heuristics and establish a set of questions that need to be answered when looking at our designs. We believed that by applying such design practises we could achieve the goal of high usability. Therefore, we formulated the chosen heuristics and the collection of questions in form of different criteria as follows.

CRITERIA 1:

a) The user experience goals as described by Preece et al. [8]. A system should be satisfying, enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing, supportive of creativity, rewarding, emotionally fulfilling etc.

b) The usability goals described by Preece et al. [8]. A system should be efficient to use, effective to use, safe to use, have good utility, easy to learn, and easy to remember.

CRITERIA 2:
The use qualities of digital designs articulated by Löwgren [5]: anticipation, surprise, playability, seductivity, social actability, transparency. We see these qualities as important design goals to achieve, so that the user can experience them when using the storytelling tool or the mobile client.

CRITERIA 3:
The usability heuristics defined by Nielsen [7] such as "Simple and natural dialogue" or "Speak the users' language" etc. These seem to be highly applicable when designing the mobile client and the storytelling tool in order to find out what is missing or what goes wrong.

CRITERIA 4:
The questions proposed by Instone (as quoted by Veen) [13]: a) Where am I?, b) What's here?, c) Where can I go? According to Preece et al. [8] there are few key design issues for websites that are different from other interaction designs and they can be captured by these questions. Instone explains that the answers to these questions must be clear to users.

CRITERIA 5:
a) Will users know what to do? b) Will users see how to do it? c) Will users understand from feedback whether the action was correct or not? These questions are used for a cognitive walkthrough of a design. They lean on the questions proposed by Preece et al. [8] who suggest a walkthrough as an alternative approach to heuristic evaluation for predicting the users' problems without doing user testing.

CRITERIA 6:
a) Why should I join this community? b) What are the rules? c) Can I do what I want to do easily? d) Can I express myself as I wish? These are heuristics from online community website design. According to Preece et al. [8], a key concern is how to evaluate not merely usability but how well social interaction is supported, in this case especially sociability. We chose these because the storytelling tool of Story Mashup exhibits significant character of an online community tool.

3.2 DESIGN PROCESS

To manage our design process, we tended to lean towards Nielsen's established usability engineering life cycle, focusing especially on prototyping and iterative design [7]. This includes in our case on one hand applying the set of identified design criteria, and on the other hand conducting tests in the lab and in the true environment of use, for the purpose of obtaining feedback for the iterative design.

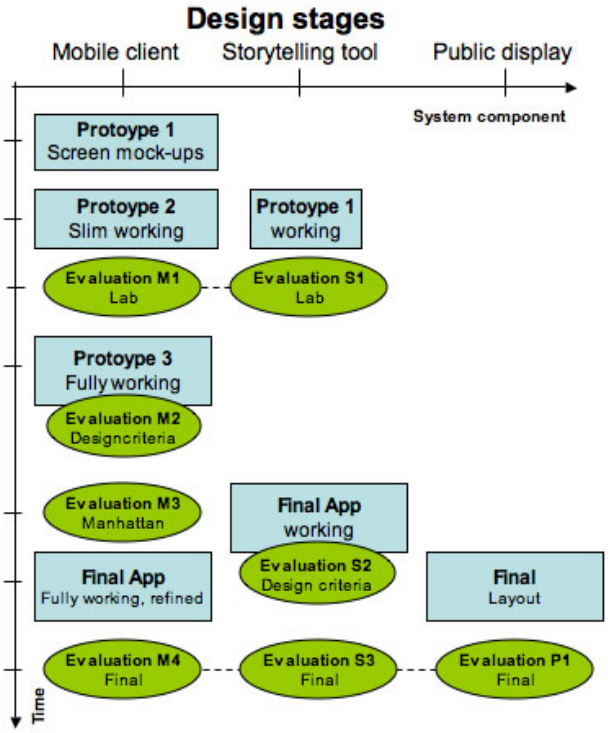


Figure 3. Design stages

We believe that by using prototyping and a fast iterative design cycle we can achieve our goals of high usability and successful interaction, since the instant feedback from evaluations can be incorporated in the design of the next prototype.

Fig. 3 gives an overview of the different design stages of each component, placing the different prototypes and evaluations on a timeline. While the prototypes have running numbering, the evaluations have unique identifiers, e.g. M1 or E2. Discussion on the final evalu-

ation of the three components of the complete system (M4, S3, P1) is deferred till Section 4.

3.2.1 DESIGNING THE MOBILE CLIENT

Given the basic idea of the game, at the very beginning we knew only the general tasks of a mobile player such as shooting a photo and accepting keywords. We had no clear understanding what the mobile client should provide the player with in terms of features, UI modes, timings etc.

Identifying these requirements was part of the design process. Our challenge was to incorporate the complex underlying game mechanisms into the mobile client and make them transparent on the UI level. We wanted to provide the user with a simple UI, which would allow her to concentrate on the main tasks of the game, the creative tasks, instead of being occupied and interrupted by multiple UI navigation steps etc. To meet this challenge we built three prototypes of the mobile client en route to the final game version.

PROTOTYPE 1. Based on the ideas of the basic game mechanisms we designed a flow diagram including all possible UI view modes and task selection options, in the form of UI screen mock-ups (Fig. 4).

While creating the mock-ups, we were able to make cognitive walkthroughs applying criteria 5a) Will users know what to do? 5b) Will users see how to do it? 4 a) Where am I? 4b) What's here? and 4c) Where can I go? By asking ourselves these questions we came up with the most essential functionalities we believed would provide the user with an engaging experience when using the mobile client and would allow concentrating on the creative tasks of the game.

PROTOTYPE 2. Given the paper prototype 1, we implemented a vertical prototype of the mobile client. It was fully functional in terms of camera usage, data upload and the notification of incoming keywords as well as sending and receiving an image for guessing. However, high quality graphical design was omitted and feedback for the user's actions was only available as text on the screen.

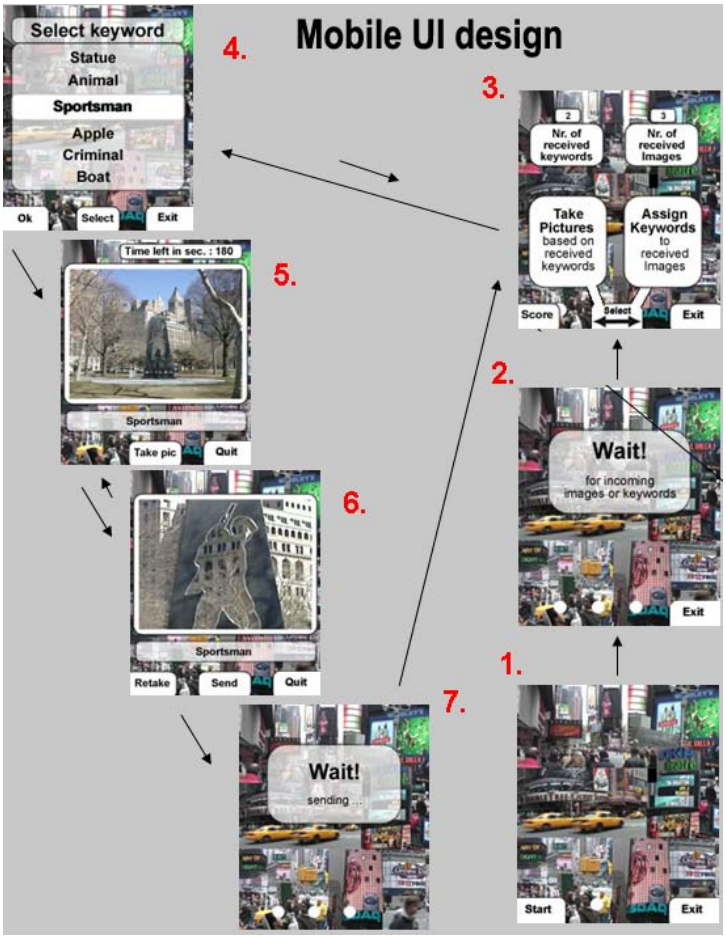


Figure 4. Initial mobile client UI screen mock-ups.

Evaluation in the lab (M1). Prototype 2 was subjected to a usability test in a lab. Six test users played the game for 1.5 hours, dividing their attention between the mobile client and the storytelling tool (see evaluation S1). We collected data by conducting video interviews with each player and observed players by recording their actions.

The findings of the evaluation showed a clear need to provide a status indication in which part of the application the user was at any given time. Further, we needed to come up with a clear navigation structure. Also, we needed to implement a scoring scheme that allows players to gain points and to be able to track them. Another important issue to solve was to provide proper feedback to confirm actions taken by the user and when uploads were done. Also, a status

indicator showing that the application was online and ready for receiving keywords was deemed necessary. Most importantly, we had to provide a smooth and simple UI with just 2-3 clicks needed for all actions, which would allow the user to focus on the main task. After the lab evaluation we realized that we most likely could have avoided most of the design mistakes, if we would have made another walkthrough with our set of design criteria.

PROTOTYPE 3. Going back to the drawing board, we sketched a complete redesign on paper, including a flow diagram of the tasks the client should handle.

Evaluation (M2). By taking a walkthrough on the prototype 3 we applied criteria 3 (Nielsen's [7] heuristics), for example:

- Does our application have "Simple and natural dialogues?
- Do we "Speak the users' language"?
- Have we managed to minimize user memory load?

The walkthrough allowed us to see clearly what the missing parts in our design were.

PROTOTYPE 4. Given the prototype 3 on paper, we implemented it as a functional mobile client including a rich graphical design. For each redesign we needed to make sure that any arising changes in the server side implementation were made, as well. Using Python for S60 [10] [4] as the programming language on the mobile client and Python on the server side supported efficient programming of the redesigned components.

Evaluation (M3) in Manhattan. The next step was to evaluate the new prototype in the target environment of use (Manhattan, New York), to find out about potential problems that we could encounter during the real game play and to be able to prepare for necessary backup solutions. The evaluation was done with 13 test players, five females and eight males. Each of them had a mobile phone connected to the mobile data network that we were going to use in the final game. One of the problems we had at this point was that the storytelling tool in the web was yet not ready. Therefore, we built a server component that simulated the storytelling tool by randomly drawing nouns from a database and sending them to players.

The game was played for two hours. We collected data by observing the players with a video camera during game play. We also video interviewed the players both during and after the game, getting instant feedback about the user experience. After the game ended, the players filled in a questionnaire with 26 statements, on which the users were asked to answer on a 5-point scale, and 23 open-ended questions. The questions focused on one hand on the user and game experience, on the other hand on usability issues.

From analysing the video interviews and the questionnaire we summarized a number of faults and key findings regarding the mobile client such as:

a) camera does not shoot immediately;
b) viewfinder sometimes does not show anything;
c) problems in sequence choose keyword – loading camera – guessing – keyword lost;
d) some popup notes are disturbing;
e) in certain locations the mobile data network worked very poorly or not at all.

Further, we got a range of valuable answers to the open-ended questions. Q: "What did you like most in the gameplay?" A:*"The challenge to find an object that best represented the word"; "The time aspect keeps the pacing. Like the guessing of the fact against other player"; "I liked getting / sending photos and guesses on my phone"; "Collaborating with people; playing in group was fun activity, completely transformed real world to game space."*

Q: "Suggestions for improvements?" A: *"I think you should get more points for guessing right. It feels I am just giving someone points"; "Make the score for a correct guess higher than just taking a photo + closer to getting a photo identified"*.

Q: "Was there anything confusing for you?" A: *"The scoring was a little difficult to use / understand"; "I never found the time to look at the gallery"; "Some bugs in the game. Sometimes I miss choosing a keyword"*.

One completely unexpected thing to see happening was that people acted out the nouns to take photos of, which was strongly visible in the observation videos. This strongly indicated that our interac-

tion design was successful, as well as our design approach, since one of our major design goals was to trigger creativity - it is certainly needed in acting out nouns.

Prototype 4 fared much better in its evaluation than prototype 2. At this point we realized that our design process and heuristics for evaluation had worked to a great extent. However, evaluation of prototype 4 indicated clearly that there were still some major issues to be solved, of such types that were not discovered at earlier stages of walkthroughs and applying our design criteria.

FINAL VERSION. The findings from the evaluation of prototype 4 led to some minor changes in the design of the mobile client. Since many people complained about too many pop-up notes, we replaced them with sounds. Further, we enhanced the navigation pattern to find and use the gallery. We also changed the scoring mechanism to a more balanced level. At this point the mobile client was ready to be used in the final game. The final mobile client had three UI modes (Fig. 2): Keyword selection mode, shooting (camera) mode, guessing mode and player statistics mode. A simple gallery mode should provide the player a possibility to see the most recent photos taken by other players.

3.2.2 DESIGNING THE STORYTELLING TOOL

In designing the storytelling tool, our first intermediate goal was to create a prototype with a basic set of functionalities. It was supposed to be exposed to user testing in a lab, in conjunction with the mobile client prototype 2. Testing would provide us feedback on the design, and would help in identifying further features and functionalities. Our ultimate goal was to design an intuitive interface that makes the concept of storytelling instantly clear and graspable, exhibiting good usability. As with the mobile client, we believed this could be achieved by applying the set design criteria.

PROTOTYPE 1. We started off with a first prototype that had simple graphical elements and text showing events such as the keyword that is currently sent to a mobile player and is in waiting state to be photographed and to return to the website. Also, all photos that had come back were visible in a side bar that needed to be clicked on. Another view was giving a starting point for a new story to be written.

The user could choose existing pictures with the attached keyword and sentence from the side bar and add his own sentences of which a noun was extracted automatically and sent to a mobile player.

Evaluation in the lab (S1). Prototype 1 was subjected to a user evaluation in a lab, in conjunction with the testing of the prototype 2 of the mobile client (see evaluation M1). Six test users played the game for 1.5 hours, dividing the time between the storytelling tool and the mobile client. We conducted video interviews and recorded video observations of the players while they were using the tool. The suggestions for improvement made by the test users included:

a) provide topics or themes as categories to give some idea what the story should be about;
b) re-play / re-tell histories, fairy tales;
c) provide view for seeing the evolution of stories;
d) indicate a story's readiness;
e) provide more guidance, more links, more status information;
f) give instant feedback to the author of a sentence regarding the status of the sentence;
g) provide view of most popular sentences;
h) provide a collage view of images which have been sent in.

From observing the actions of the users of using the first prototype of the storytelling tool, it became painfully clear that navigation in the tool was too complicated. Further, the users had difficulties in fully understanding what was going on, e.g. what were the steps to take to write your own story or where to click to see other people's stories.

FINAL VERSION. Given the outcome of the evaluation of the first version, we decided to completely redesign the structure and functionality of the storytelling tool. We were inspired to incorporate some of the ideas presented by the test users into the final version of the storytelling application. In designing the final version, we focused especially on the design criteria 3-6, e.g. 4a) Where am I?, 4b) What's here?, 4c) Where can I go?, 5a) "Will user know what to do?" and 5b) "Will user see how to do it?"

In the final version we elected to have a grid structure of nine squares as the main view (Fig. 5). As described in [12] in detail, each square represented one sentence to be illustrated, hence a story con-

sisted therefore of nine illustrated sentences. For each square or slot the user may either pick an already illustrated sentence, written by someone else, or she may write a new sentence by simply clicking on the square which opens a text input field. Once the user has chosen an appropriate content for each slot and the resulting story looks somewhat meaningful, she may publish the story.

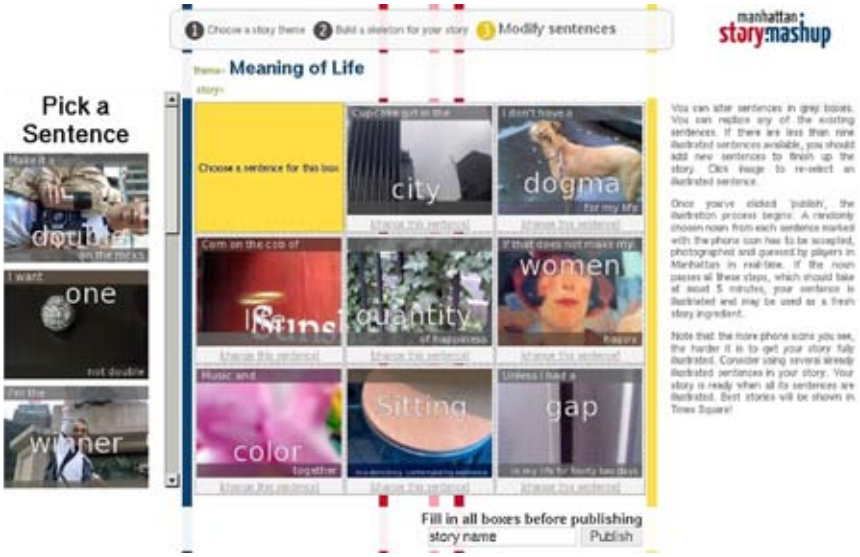


Figure 5. Storytelling tool.

In order to make access to the tool as convenient as possible, we decided to have no registration for the writers. They should be able to start playing with the tool immediately. This approach was inspired by the design criteria 6a "How do I join or leave the community" and also 6c "Can I do what I want to do easily?"

Given that people could include any kinds of sentences and words in their stories, the system performs simple filtering with a blacklist, together with some syntactical checks. The user is informed if something is wrong.

After a new story is published, the nouns are collected. From each new sentence a random noun is chosen and dispatched to randomly chosen mobile players. Then the story is moved to the pool of incomplete stories where it stays until all its sentences are illustrated.

The storytelling tool has another important feature of presenting the user on the left side of the grid a list of available illustrated sen-

tences to choose from. By clicking on images they can be selected and placed inside the story grid. This design decision was inspired by criteria 6c) "Can I do what I want to do easily?" and "Can I navigate the site?"

Evaluation (S2). As we went along designing the features, functionalities and site layout, we made cognitive walkthroughs to make design decisions. This helped us to come up quickly and easily with a solution that we felt satisfied most of the criteria.

3.2.3 DESIGNING THE PUBLIC DISPLAY

The design process of the public display was different to that of the mobile client and the storytelling tool in the sense that instead of iterative design cycle it was a one-shot go in the final game environment.

The Reuters Sign in Times Square was used as the public display during the game. The sign was chosen due to its prominent location and enormous visibility. Times Square is an iconic location in global scale, thus the possibility to create personal content to be shown there was attractive for people around the world.

Figure 6. The Reuters Sign in Times Square.

Once all nine sentences of a story had successfully gone through the illustration process, the story became a candidate for presentation on the public display. A human moderator had to "bless" a story for presentation, which was then automatically sent to the display.
The graphical layout of the display was designed with Adobe's After effects, providing animation of the nine illustrated sentences of a story. The system running the display fetched a story from the game server and displayed the rendered graphical layout. For technical and aesthetic reasons we decided to overlay the sentence on top of the photo. The entire story was shown on the display whereas each photo was enlarged one by one for six seconds on the middle display (Fig. 6).

4. FINAL EVALUATION AND LESSONS LEARNED

We report here the evaluation of the system with previously unpublished findings, and contrast them with the design rationale, to provide valuable lessons learned for the community. Sometimes we also refer explicitly to the results reported by us in [12], in order to explore our arguments posed in this paper.

The game was played on September 23rd, 2006, between 12:00am-1:30pm in midtown Manhattan. 184 players played the game. Most of them were invited university students that had shown interest in this kind of game, but also people from companies and institutions participated.

Quantitative data collected on a server log revealed that during the game 3142 photos were taken, 4529 guesses made and 115 Stories created [12].

We also collected qualitative data with a questionnaire, which was filled in immediately after the game ended. The questionnaire for mobile players contained 26 statements on a 5-point scale between 1 (disagree completely) and 5 (agree completely). Additionally, 23 open-ended questions were presented. In total 99 questionnaires were returned, 56 from males and 43 from females. 24 players were of age 18-24, 64 of age 25-34, and 15 of age 35+. Upon returning the questionnaire, each player got an invitation to an evening party. We

also observed the players during the game with a video camera. After the game was over, a few individual users and few groups of users were interviewed using video. The questionnaire for web players using the storytelling tool was available at the Story Mashup website. Seven people filled in the questionnaire.

In the following, we discuss the findings of our experiment to contrast them with our design goals.

4.1 MOBILE CLIENT

A) ENGAGING EXPERIENCES

The replies to the open-ended question "What did you like most in the gameplay? Please define the most interesting aspects..." gives us some first insights. Of the 99 respondents 41 mentioned "shooting photos", 7 "guessing part of the game", 15 listed both and 26 users gave other answers. This means that 73 out of 99 players favored just two game features: "shooting photos" and "guessing". Results reported by us in [12] supported these findings: people gave photo hunting and guessing keywords average rates of 4.63 and 4.39, respectively, on a 5-point scale. This shows that we succeeded in achieving our design goal of providing engaging experiences. In section 4.5 we look in detail at the aspects of players' enjoyment of Story Mashup, to explore this phenomena further.

Further, we were interested to get some answers to the question "Was there anything confusing or something you didn´t like? Please describe..." and received following answers: *"The server crashed a couple of times"; "Crashes / connection failures"; "Server problems, application quit unexpectedly"; "App crashed many times. Server crashed - very annoying"*. The game server had some problems for some period of time during the game play and the mobile client was not fully functional during that period. However, people were not overall frustrated since the total game experience was very strong. This became clear in video interviews of the players as well.

B) CREATIVITY

A very strong observation was that people were acting out keywords when they could not find a suitable object to take a photo of. The use of imagination and original ideas in the production of the pho-

tos took place. This shows that we succeeded in designing the mobile client in such a way that it triggered creativity, which was one of the major design goals. Clearly, the use of the mobile device as an interaction device and as an image capturing device in the context of the Story Mashup system is strong. The question "Do you think the Story Mashup game is supportive for creativity" received following answers: *"Makes you figure out illustrations for words"; "Yes, especially when you must act out complex words"; "Yes, mime effect pushes creativity"; "Yes, because some words are not easy to find"; "Yes, teaches you to be abstract in conception"*. Some of the answers to the question: "What did you like most in the gameplay? Please define the most interesting aspects..." reflects this as well*: "Taking pictures related to images and having people enacting them was cool!"; "The creativity involved"; "The free association process"; "The narrative/ contribution part"*.

C) TEAMPLAY

One of our design goals was to foster collaboration and social interaction in form of team play. For us it was interesting to see if the mobile device could serve as a facilitator for such purposes. Indeed, it appeared that this was the case, since the completion of tasks where team play occurs is centered on the mobile.

The question "If you played in a team, what motivated you to join in the first place?" received following answers: *"Group energy"; "Helping each other with the words"; "Collaborating in hunting for pictures"; "To have fun with friends"; "Playing in a team helped in finding pictures, guessing"; "Collective excitement"; "Getting team members to act out keywords"; "Makes it more fun"*. Some similar answers were also given regarding the question: "What did you like most in the gameplay? Please define the most interesting aspects...": *"Playing in a group and doing silly things for pictures"; "Spread out yet collaborative spirit"; "Competition and kicking everyone´s asses"*. We can conclude that Story Mashup triggers collaboration and social interaction in form of team play.

D) USABILITY

Having applied the various design practices as discussed in section 2 and especially in section 3.2.1, we were interested to see what level

of usability we had reached in our mobile client. Table 1 shows the average ratings of 99 mobile players on ten different statements assessing the usability. The first three rows of the table were reported by us in [12] and are used here to explore our argument.

The rating 3.19 for "The mobile application was easy to use" as well as 4.18 for "When I was holding the phone, I felt confident hunting for images and doing the guessing part" indicates strongly that we got many things right with our mobile client, especially regarding the application of our design criteria 1 on usability goals and criteria 2 on use qualities of digital designs. Also, regarding our design criteria 3 covering Nielsen's heuristics and criteria 4 "Where am I?", "What's here?", "Where can I go?", we can see that they helped us to bring fruitful results. The rating 3.65 for "The pop-up notes and instructions on the phone were clear" and the rating 3.51 for "At any given moment it was clear to me what I was supposed to do" as well as 3,72 for "It was clear to me which button to press to navigate" support this conclusion.

We failed to discover that viewing photos in the gallery of the mobile client is less important to the mobile player than we anticipated. Rating 2.15 for "It was important to me to view my and other players' photos in the gallery of the game client" clearly shows that this feature was not really popular.

Table 1. Usability ratings by mobile players.

When I was holding the phone, I felt confident hunting for images and doing the guessing part	4,18
The mobile application was easy to use	3,19
At any given moment it was clear to me what I was supposed to do	3,51
It was clear to me which button to press to navigate	3,72
The pop-up notes and instructions on the phone were clear	3,65
I had enough time to accept a keyword, take a photo and to guess	3,5
I was able to compare my performance against other players	3,39
It was important to me to view my and other players photos in the gallery of the game client	2,15

This is also reflected by question "How many times did you check photos in the gallery of the game client? Please describe..." Out of 99 persons, 11 used the photo gallery 2-3 times, 10 once, 36 never, 3 never/too busy taking photos, 3 at the end of the game, 1 every time

when scoring, 6 when the game was down and 4 didn‘t know about the feature. 25 persons did not answer the question. This shows that this feature was hardly used within the main game flow. It seems that players were occupied by shooting photos and guessing nouns, in order to gain as many points as possible.

DESIGN LESSONS LEARNED:

1. **Fast iterative design cycle utilizing Python for S60**. By employing a fast iterative design cycle and the use of Python for S60 [10] [4] we were able to implement improvements quickly for each new prototype and test them out. For example, we were able to improve the scoring mechanism feature on the mobile client significantly from rating 3.18 in the first lab test (M1) to the 4.25 rating of the final game play.

2. **Replacing pop-up notes with suitable sounds**. The use of pop-up notes should be carefully planned since they can easily be bothering for people. For us it turned out to be a good thing is to replace them with suitable sounds instead.

3. **1-2 clicks to complete a task**. A mobile client used in activities such as in our system should provide the user with 1-2 clicks to complete a task. This reduces the cognitive load.

4. **Building an integrated custom mobile client is essential**. The fact that the mobile application does many things automatically e.g. open the camera, send and receive images and keywords in the background without the user's action, it allows her to concentrate on the more creative tasks in a seamless experience. We believe it would have been extremely difficult for people to use the native camera or SMS/MMS messaging applications as independent units for playing Story Mashup - due to their clumsiness and time consumption in handling them.

5. **The mobile phone is ideal for designing mobile interaction applications**. Having so many features such as camera, sound, graphics, keyboard keys, access to internet etc. available in a small device, allows designing of powerful integrated applications with many functionalities that are often needed for mobile interaction systems. We were able to add step-by-step new functionalities to the Story Mashup client, based on the needs identified by testers when

going through the prototyping design phases. And luckily the mobile phone offered all of them.

4.2 STORYTELLING TOOL

We give here some insights to our findings, even though our data is not as strong as on the mobile client since only 7 people filled in the online questionnaire.

A) ENGAGING EXPERIENCES

The rating of 4.6 regarding the statement "It was fun and engaging to play this game" is very high. It is obvious that also the web users perceived the game as engaging experience. This means that our design goal was successfully met. The question "Do you want to play this game again?" received answers such *as "Yes, please !!!!! It could lead to addiction, cause it is so much fun to write stories to the topics you offered and to wait how they will develop."; "Now that I have the hang of it, I'm thinking of new ways to play it..."*.

B) CREATIVITY

To the question "Do you think the Story Mashup game is supportive of creativity?" we got answers such as *"You decide and value sentences and try to improve or adapt their meaning. You search for other possibilities while your decision what you want to express drives you there. You have to find new words and you try to remember which keywords you already had seen. So you put together what you already know and find a new expression - very creative!"; "Yes, Storymashup is supportive in creativity because it engaged you to use what was there to create new sentences and in turn creating new stories."* Thus, regarding the design goal of triggering creativity we succeeded on the web part of our system, as well.

C) USABILITY

The usability of the storytelling tool turned out to be worse in comparison to the mobile client and the web users provided mixed feedback. Though, it was interesting to observe that bloggers with lots of prior experience in contributing own things to the web had far less problems than inexperienced users. This difference is apparent

in the answers to the question "Do you think it is easy to play this game?": *"Yes, of course it is easy, because you can change small things and will have a result. The pictures and sentences which are already there bring you associations and ideas."; "I found it difficult to figure out how to add new sentences. I finished one story with no new sentences and got a message saying "Next time add new sentences", and I felt a little annoyed about that. Eventually I figured it out, though."* The rating of 2.5 to the statement "At any given moment it was clear to me what I can do next (build story, wait for images...)" and rating 3.5 for "It was clear to me which button to press to navigate inside the storytelling tool" indicate that we did not achieve our design goal of high usability on the storytelling tool.

DESIGN LESSONS LEARNED:

The storytelling tool lacked the finishing touch since we could not carry through all the planned development stages due to the lack of time. Nevertheless, we believe the storytelling tool can to be developed into a more advanced form including more functionalities and improved usability.

We think by designing tools as the storytelling tool as part of the Story Mashup system, new experiences can be delivered to web users due to the real-time aspect happening in the physical space – in our case the instant generating of images based on users web activity.

4.3 PUBLIC DISPLAY

The questionnaire data gives some idea of to what extent the public display enhanced the mobile players' game experience. For this exploration we refer to one finding that we reported in [12] in a different context: "For me it was an important part of this game to see the illustrated stories at the public display at Times Square" ranged from 1 (disagree completely) to 5 (agree completely) so that the average rating was 3.28. We dare to conclude that for the majority of the mobile players the public display was an integral part of the overall game experience. Though, there was also a significant amount of players to whom the public display was not as relevant. Therefore, the Story Mashup could possibly work as a game and as a real-time publishing environment without it.

4.4 MOBILE, WEB AND PUBLIC DISPLAY AS A COLLABORATIVE REAL-TIME AUTHORING SYSTEM

For us it was very interesting to see how the mobile client, the web and the public display could work together as a collaborative real-time multimedia authoring system. We were also looking for things that we could learn from a working system implementation.

To assess how people felt to be part of such a collaborative authoring system and what was their perception when being involved, we posed a number of statements to the mobile players and the web players.

Table 2 shows the average ratings of selected statements. These numbers show that the majority of the mobile players were aware of the overall game design and they had a sense of being the ones who are carrying out an externalised highly cognitive task originated from the web users.

It is interesting to see that the web users rated the statement "I felt I belonged to a joint, collaborative action contributing to a common goal" with 4.5, which is significantly higher than from the mobile players. However, we are aware that the data on web users is weak due to the small number of respondents (7).

Also, we have succeeded in designing a system that provides engaging experiences, which has been identified by Brignull [2] as an important part of interaction with large screens.

Table 2. Ratings regarding the mobile and the web as a joint system.

	Mobile	Web
I felt I belonged to a joint, collaborative action contributing to a common goal (reported in [12] already)	3.59	4.5
It was easy for me to find objects to shoot photos based on the keyword	3.34	N/A
While playing I felt I was part of a joint activity between players on the web and mobile players in Manhattan	3.22	N/A
I was aware that I contributed images to other people's stories	3.19	N/A
It was clear to me that the keywords were coming from stories of players on the web	2.28	N/A

4.5 PLAYER'S ENJOYMENT

Finally, we use the GameFlow model by Sweetser and Wyeth [11], to understand why Story Mashup produces the strong enjoyment stated by the players.

CHALLENGE: Games should be sufficiently challenging and match the player's skill level. In Story Mashup, players had two challenges: to shoot images and the guessing part. Also, the race-against-clock-factor was present as well as the competitive style of play.

CONTROL: Players should feel a sense of control over their actions in the game. In Story Mashup, players were able to choose keywords from a list at their convenience and own speed in order to start the action of shooting a photo. Also, they had the freedom to do the guessing part or not.

CLEAR GOALS: Games should provide the player with clear goals at appropriate times. In Story Mashup, players had to score points by shooting good images that can be guessed by others, but also by guessing other players' photo correctly.

FEEDBACK: Players must receive appropriate feedback at appropriate times. In Story Mashup, players were constantly able to check their rank. A sound informed them when their score increased.

IMMERSION: Players should experience deep but effortless involvement in the game. In Story Mashup, players expressed in video interviews e.g. *"Usually you are aware of strangers and people passing by. But this, you kind of ignore them and do crazy stuff"; "It actually feels like I´m really immersed, and then that helped me to do these strange things which I would feel otherwise uncomfortable in doing it publicly."*

SOCIAL INTERACTION: Games should support and create opportunities for social interaction. In Story Mashup, players were often playing in groups to act out keywords.

5. CONCLUSIONS

The Story Mashup system introduces a new form of interactive storytelling by mobile and web users. We studied the design process of combining a mobile client, a storytelling tool in the web and a large public display into a collaborative street art authoring system de-

ploying ubiquitous multimedia. By exploring the findings from the empirical evaluation in the true environment of use we showed that by applying the chosen design process and a set of design criteria we were able to make good design decisions and achieved the design goals of providing engaging experiences, triggering creativity and fostering collaboration and social interaction in form of team play.

Reporting the experience and knowledge on how to design such a system has relevance in informing the design of future mobile services that aim to combine the virtual and physical space, offering mobile and web users a seamless collaborative experience in real-time.

While current design methods still work, we can also clearly see there is need to develop new methods in order to live up to the forthcoming design needs for designing real-time mobile interaction systems that combine the web and the mobile space that go beyond Story Mashup. In this regard it felt to have just stepped into an area that needs more exploration and future research.

The Story Mashup system could well suit for educational purposes, even across city and country boarders. The use of video or other multimedia pieces would increase the presentation power over still images and would open many new opportunities on how the Story Mashup system could be utilized.

6. ACKNOWLEDGMENTS

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Article 4:

"MobiToss: A novel gesture based interface for creating and sharing mobile multimedia art on large public displays"

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ABSTRACT

This paper presents MobiToss, a novel application for creating and sharing mobile multimedia art with an off-the-shelf mobile phone equipped with built-in accelerometer sensors allowing gesture control. The user first takes a photo or captures a video with the phone and then using a 'throwing' gesture transfers the clip onto a large public display for instant viewing and manipulation by tilting the phone in different directions. The system augments the user-created clip with other items such as music or brand labels and the encoded clip is automatically sent back to the phone as a personal artefact of the event. The clip is also uploaded to a dedicated community website for sharing the created multimedia art with others. MobiToss could be deployed e.g. in clubs, pubs and concerts as a participatory VJ-tool. In addition to the design the paper presents the results of a preliminary user evaluation, which highlight the novel art experience provided by MobiToss.

CATEGORIES AND SUBJECT DESCRIPTORS

H.5.2 [**Information Interfaces and Presentation]:** User Interfaces – *evaluation and methodology, input devices and strategies, interaction styles.*

GENERAL TERMS
Design, Experimentation, Human Factors.

KEYWORDS
Gesture control, experimental evaluation, interactive content, public display.

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1. INTRODUCTION

MobiToss combines standard interaction devices (mobile phone, large public display, web), interaction styles (mobile phone UI, gesture control) and multimedia processing techniques into a novel system for creating and sharing mobile multimedia art. Of particular interest is the gesture control with a mobile phone equipped with built-in accelerometer sensors. Having shot a video with the phone the user can 'throw' the clip onto a large public display for instant viewing. Then the user can manipulate the video on the public display by tilting the phone in different directions.

Kela et al. [6] indicated in their study on accelerometer-based gesture control for a design environment that different people usually prefer different gestures for the same task, and hence it should be possible to personalize the gestures. By using the throwing gesture, MobiToss relies on a commonly understood gesture 'throwing something to somewhere'. However, the challenge is to design the system in such a way that different forms of throwing can be used reliably and intuitively.

Many people are used to throwing physical objects, but throwing digital media is a new concept. Bertelsen et al. [1] report a video pro-

totype in which digital documents are positioned on walls and floors by throwing a ball at the wall or bouncing it onto the floor. They argue that the interaction with the ball serves to establish new relationships to the digital materials manipulated. MobiToss provides a starting point for exploring the throwing gesture in the context of digital media and collaborative screen based entertainment using a commercial mobile phone.

The Wii game console [8] introduced a new way of interacting with games on a large screen. While the Wii controller is just a gesture control device, a modern mobile phone has many additional features. It allows creating content as well as being wirelessly connected, and contains a built-in accelerometer sensor for gesture control (e.g. Nokia N95 and Nokia 5500). MobiToss combines these features into a single application.

Vajk et al. [10] presented a system that connects the mobile phone to large public game screens over Bluetooth and turns the phone into a game controller in a multiplayer game. They highlight that this type of control can be both intuitive and fun. Similarly, SQEAK [7] employed mobile phones with attached miniature accelerometers for gesture based group interaction with public displays.

While exploring the use of a mobile device as an artistic tool in public spaces, Clay et al. [2] concluded in their mobile music work 'China Gates' that using wearable computing technology within global ubiquitous networks as an art tool allows interacting with society as part of a collective.

This paper is organized as follows. Section 2 describes the MobiToss system. Section 3 presents the initial experimental evaluation of the system in the true environment of use and discusses the important findings and future work. Section 4 concludes the paper.

2. THE MOBITOSS SYSTEM

The user first captures a photo or video with a personal mobile phone and then 'throws' it onto the large public display by making a throwing gesture with the mobile phone, as illustrated in Figure 1. Upon a 'recognized' throw a matching sound is provided by the phone as feedback for success and the content is instantly visible on the screen.

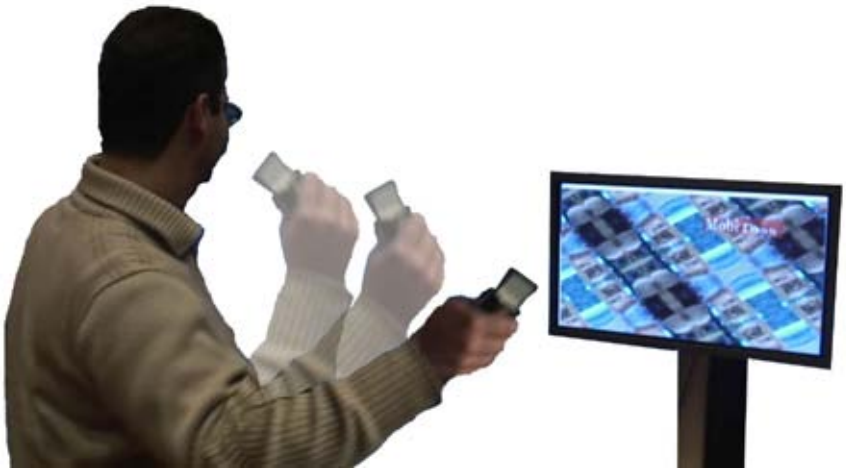

Figure 1. Throwing a video to the large screen.

Figure 2. Gesture control to manipulate video.

The user can manipulate the appearance of the video or photo on the screen by moving the phone up, down, left or right, as shown in Figure 2. The movements correspond to different video effects and graphical filters such as matrix, kaleidoscope, spiral distortion and color saturation. For example the matrix effect multiplies the video over a number of rows and columns and by tilting the phone forward or backward, this number can be increased or decreased, which leads to a zoom effect. Using the spiral distortion effect the user can make the entire content rotate around the centre of the screen, or via the color saturation effect all colors of the video can be saturated by the same degree etc. The video effects provide a means for creat-

ing artistic outcomes but could also be used as built-in censorship mechanism for inappropriate content.

The produced artefact, viewable by everyone, is recorded into a new 30-second video clip and encoded with a commercial pop song, a logo and a web address as advertisement. The encoded mash-up clip is then automatically uploaded to the users' phone as a personal reward and memory of the created artefact (Figure 3). The mash-up clip is also uploaded to a dedicated community website, to collect the clips and to make them available to other users and to share them with friends. The website can be configured for creating event and location based collections.

There are several reasons why the mobile phone is a highly suitable user device for MobiToss. First, as the personal trusted device it stimulates use and removes need for any proprietary application specific devices. Second, there are already several phones with built-in accelerometer sensors on the market and they are predicted to become increasingly widespread. Third, they provide the functionality to create content by the users and allow anonymous, wireless participation in a joint social public group interaction. Fourth, the mobile phone provides a reliable return channel for delivering confidential user specific content back to the user, such as the music video including logos and web links as advertisement.

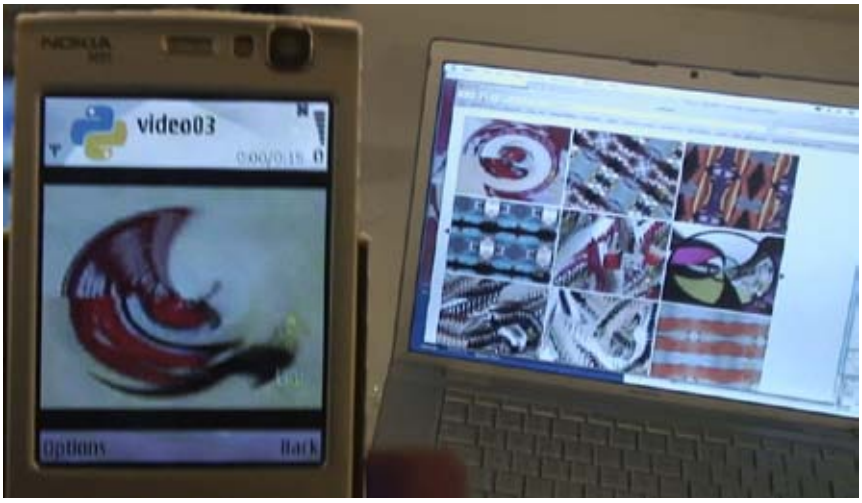

Figure 3. Mash-up clip on phone and community website.

The MobiToss system is realized with a client-server architecture, which comprises of four components: 1. A Symbian client application running on a mobile phone with built-in accelerometer. 2. A server running on a PC for creating the clips. 3. A large public display showing the video. 4. A dedicated community website for collecting the clips.

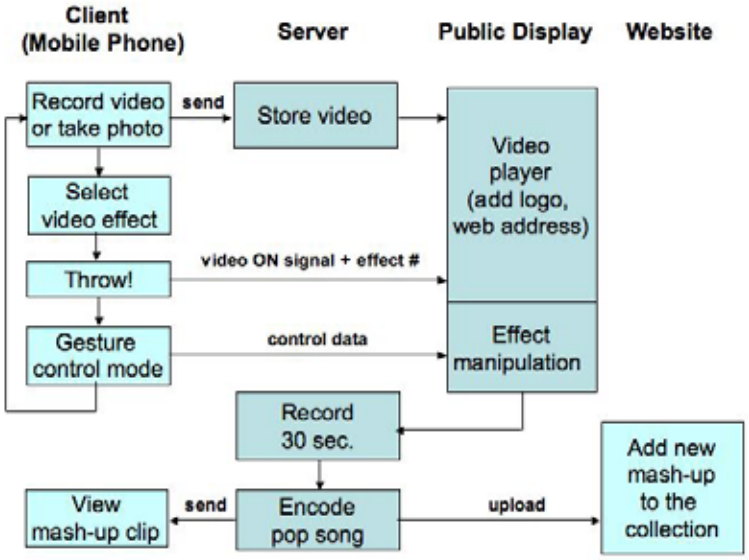

Figure 4. State diagram of the MobiToss system.

The client is implemented in Python for S60 [9] that allows the reading of the built-in accelerometer sensor data as well as shooting of photos and videos by a single application. The client also executes a range of tasks automatically in the background such as uploading/downloading of content or controlling the video manipulation on the server. The client communicates with the server using the HTTP protocol and sockets over WLAN (IEEE 802.11) connection. Bluetooth connectivity is not used since it would restrict participation to a limited number of users (8 max) within a limited spatial range of about 10 meter radius from the service point. Using WLAN provides sufficient data rate and allows participation from much greater distances, for example throughout a concert held in a large arena.

Figure 4 shows the state diagram of the system. First, the user chooses from a menu to either take a photo or to record a video. The

selection invokes automatically the camera's viewfinder. The recording period is set by pressing the start and end buttons (Figure 5(a)). The phone then sends the video to the server where it is stored and handed to the video player of the public display. Next, the user is provided with a menu to select a video effect (Figure 5(b)) for manipulating the video on the public display. Each effect comprises of a set of parameters for later remote manipulation of the video's appearance. The selection of the video effect at this point serves the purpose of giving the user control over the initial visual appearance of his or her video before it can be seen on the public screen.

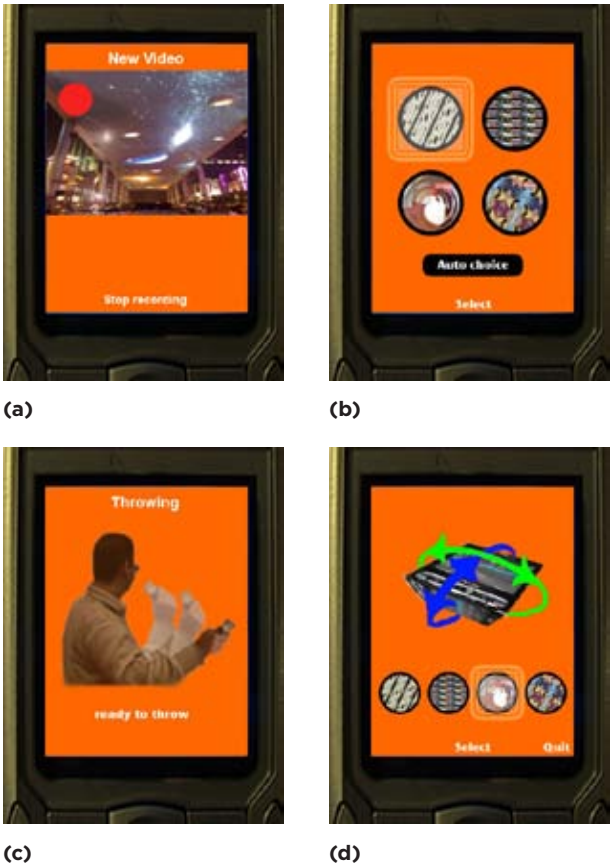

Figure 5. Screenshots of the client UI: (a) the video recording has started; (b) video effect to be selected; (c) the application is ready for throwing the video; (d) gesture control mode is active.

Once the sending of the video is complete (measured in seconds), the phone notifies the user that (s)he can now throw the video by playing a sound and by displaying a 'Ready to throw' message (Figure 5(c)).

When a throwing motion of the phone (Figure 1) results in accelerometer readings exceeding certain thresholds, the client sends an HTTP request to the server to make the video visible ('video ON signal'). The client switches immediately into gesture control mode (Figure 5(d)) and uses socket communication with the server to transmit control signals for real-time manipulation of the video. The control bytes are generated from the accelerometer readings reflecting the phone movements such as tilting left/right or forward/backward (Figure 2). This is the time when the user can create his or her visual art piece on the large screen. The creative experience is enhanced by the possibility to use the phone's navigation keys to switch in real-time between different video effects (Figure 5(d)). When the system enters the gesture control mode the server starts recording a 30-second a clip of the video as it appears on the public screen. Once the recording is complete, the server encodes a pop song into the clip. The encoded clip is automatically sent back to the phone and uploaded to the community website.

The server implemented in Max/MSP Jitter [5] handles all video effects and adds graphic elements such as brand icons and web links to the video. It also records the 30-second video. Additional components include the ffmpeg software [3] for adding the music into the clip, and some simple Python scripts for connectivity and server management.

The large display with sufficient presentation capacity serves as the main public user interface for the group, while the mobile phone provides a private GUI and return channel to the user. The community website (Figure 3) is there to collect the final clips. Anytime a new clip is generated it is automatically uploaded to the website. This provides a channel to make the clips available to other users, and to share them with friends. The MobiToss system can be configured so that it can create event or location based collections.

3. USER EVALUATION

The first evaluation of MobiToss with real users was carried out at a social event of an international conference. The goal was to obtain first impressions on how the system is perceived by the users and to identify the strengths and weaknesses as input for the next design cycle. As shown in Figure 2, the public display was located 2-5 meters in front of the users. Each user was given a Nokia N95 phone containing the client application, and shown how to start the client. Approximately 25 people, most of them researchers on mobile multimedia, tested the system and feedback was collected from 11 persons via video interviews.

In the following, we present the issues that caught our's and test user's attention. As there is insufficient space in this paper to analyze these issues in detail, significant factors are presented in the form of the answers and comments given by test users in response to a series of questions by the researchers. *Test user's comments are printed in italic*.

A clear general observation was that people enjoyed the idea of 'throwing' and playing with the system. Question: How was your experience using MobiToss? *"The throwing is the best, I like it". "It is very reactive, I didn't expect this reaction, it works well."; "It is pretty nice tool for a social event like this because you can capture the event live and you can have some fun. I like that it meshes the technological stuff with the artistic effects"; "It's fun to recognize other people in the video."*

UI ISSUES. We observed that different people do their throwing movement in many different ways, confirming Kela's finding [6]. The current implementation did not successfully detect all users' throwing gesture. User feedback brought up ideas for developing the UI further: *"Have on the phone screen an animated preview of the possible effects to see what they do"; "Reduce the number of video effects, probably have only 2-3 very clear ones to explore the system, and maybe you are more immersed.";* This indicates a need for careful UI redesign, making the relationship more clear between effect parameters and the interaction.

MOTIVATION FOR PARTICIPATION. MobiToss succeeds in providing a tool for artistic expression. *"Having the feeling I can produce*

my own pieces of art"; "If I could impress other people with doing the thing, than I would be ready to pay e.g. 50 cent"; "I would put the faces of my friends and my pet there."; "To get the music piece together with the ready art piece sent your phone is nice". It seems people need to get something out of it when using MobiToss, and doing something artistic appears to fill in on this.

IMMERSION AND PERCEPTION ISSUES. Whereas using MobiToss was a fun experience to many, it became obvious that the perception of what is going on and what interaction causes what, couldn't be fully grasped. *"I didn't really feel immersed. For me it would mean that I am attracted to the screen while I am interacting, so that I have the feeling that even I can contribute to the evolving piece of Art"; "It didn't have as much meaning as it would have if you would be able to identify things more clearly in the video"; "One has to try it out few times to figure it out."* This indicates that the system needs still a careful redesign of the video effects and its manipulation parameters.

COMMERCIAL ASPECTS. We were interested to know if users would be ready to pay money for downloading the client application. *"It depends, if I download it once and use as much as I want, then it is ok for me to pay. But if you would have to pay every time you go to a party, or if its time based payment, then probably not."; "It would be better if you can customize the filters and effects and give the people options to buy them separately. It would depend on the quality and how artistic they are on how much they cost."* It appears that some people would be ready to pay a small amount and exploring various payment models might be feasible.

COLLABORATION ASPECTS. The participants' feedback speaks in favour of having more than one person to throw their video and interact with the screen at the same time: *"Maybe you could have a competition with a split screen and you can compare the two players outcome in real-time."; "When several people throw their video - depending on the starting time of throwing - they can collide and depending on the crash a new thing is created.";* To bring in elements of competition and group play is certainly enriching for MobiToss and should therefore be integrated in the future.

ADVERTISEMENT. MobiToss can encode branding content as well as music into the user-generated mobile multimedia art clip that re-

sides in peoples phones but also on the public sharing website. This offers great opportunities for placing advertisements in a new way.

4. CONCLUSIONS

This work shows that capturing and throwing mobile content onto a large screen and manipulating it with gesture control into an art piece was perceived as a fun activity. The concepts of "me the artist" and "my art piece creation" are very relevant to the users of MobiToss. Having these concepts combined with the social aspect as well as the fact that the audience can join easily, makes MobiToss a potential new form of input to mobile community websites, e.g. as a participatory VJ tool or a public performance system. Community websites such as YouTube, Flickr or SeeMeTV have become important parts of the Internet, combining user-generated content with advertising. The so-called GENERATION C phenomenon [4] is emerging. It refers to the avalanche of user-generated 'content' in the web where terra-bytes of new texts, images, audio and video are accumulated at an ever increasing rate. The underlying driver seems to be that we are all artists, but until now we neither had the personal drive nor the means to pursue this goal. Therefore, there is a need for better tools to create, to produce, and to participate. And systems such as MobiToss could serve as new types of collaborative tools for creating novel forms of input and participation to community websites, possibly coupled with commercial content.

Although MobiToss worked reasonably well in terms of engaging users and their creativity, it requires further development in order to give the users the intended full-scale experience, e.g. by applying a more balanced set of video effects, adding group interaction and a more intuitive UI. Further, the system can also be expanded in different ways, e.g. into a collaborative tool in meeting or class rooms, where everyone can just throw their content to the large screen and control it from their own seat, or into a remote browser for photo, video or other content.

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Article 5:

"MobiSpray: Mobile Phone as Virtual Spray Can for Painting BIG Anytime Anywhere on Anything"

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Timo Ojala, University of Oulu

ABSTRACT

This paper presents MobiSpray, a novel interactive art tool for creating ubiquitous ephemeral digital art. The mobile phone is employed as a virtual spray can to spray dabs of digital paint onto the physical environment via large-scale projections. The gesture-based control of the mobile phone provides a natural pointing mechanism for the virtual spray can. Experiences from extensive field use around the world testify in favor of a successful design. Most importantly, MobiSpray liberates and empowers the artist to change the environment via large-scale artistic expressions.

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1. INTRODUCTION

This work stems from our desire to change, through digital art, the appearance of the physical environment to something different, unexpected and unpredictable, but without inflicting any permanent or illicit damage. To achieve this, we developed the MobiSpray art tool for imposing large-scale ephemeral digital artistic projections on the environment. They serve as a vehicle for experiencing space and

Figure 1 MobiSpray in action.

time in new ways, drawing inspiration both from the artistic process itself and the final artistic outcome.

MobiSpray combines existing technologies into a novel art tool. A mobile phone is employed as a virtual spray can. A drawing client on the mobile phone (i.e. the virtual spray can) communicates wirelessly with a drawing server on a standard PC for the purpose of painting on a virtual canvas. The canvas is projected with a video projector onto some backdrop. The projection distance and surface determine the scale, appearance and visibility of the resulting artistic presentation. MobiSpray is truly ubiquitous, as the equipment can be carried in a rucksack, allowing the creation of ephemeral digital art anytime, anywhere, and on anything (Figure 1). For us, MobiSpray has become a creative tool to paint wherever we go (Figure 2). We also at times take the opportunity to turn ugly looking trash into treasure, at least temporarily (Figure 3). All projections shown on photos are projections on real buildings or objects.

Creating art with mobile phones in public spaces is an emerging form of artistic expression. While MobiSpray is related to light art or light graffiti (e.g. Blinkenlights [1]), it is also a form of mobile inter-

Figure 3 Trash to Treasure.

active art within the field of media arts. The ephemeral projections onto the environment relate the MobiSpray to land art [2] or environmental art [3] (e.g. Christo [4]), in which landscape and the art work are inextricably linked and the intention of the artist is to cause no harm to nature or environment through the artwork.

The innovative aspect of MobiSpray lies in the provision of a novel, portable, gesture controlled art tool for creating large-scale full color projections in the environment in real-time. Related drawing interfaces include Cho's motion-sensitive brush [5], whose big movements result in big strokes while smaller ones produce thinner lines. In 'Drawn,' [6] painted ink forms appear to come to life, rising off the page and interacting with the very hands that drew them. 'Remote interactive graffiti' [7] invites distributed internet participants to "draw" via a browser enabled interface on a common - installation based - canvas such as a whiteboard or a projection on a sidewalk of a street.

MobiSpray employs the gesture-control of a mobile phone to provide a natural interface that allows the mobile phone to be manipulated as a spray can for painting. Related work includes MobiToss, a rare example of employing a gesture-controlled mobile phone as an art tool [8]. In MobiToss, a photo or video is first captured with a camera phone and then 'thrown' onto a public display for the purpose of manipulating it with effects and gesture-control of the phone. Garner, Rashid, Coulton and Edwards [9] employed a mobile phone as a digital 'spray can' for the purpose of reading and writing RFID tags attached to particular locations, as the digital age's virtual and undamaging version of the genuine spray can graffiti. The WiiSpray turns a real spray can into a digital spray can by placing a Nintendo Wii controller inside the can to create digital graffiti on a TV set [10].

Figure 2 Examples of MobiSpray's 'World Tour': Potts Point Neighborhood, Sydney (upper left), Guggenheim museum, New York (upper right), Houses of Parliament, London (lower left), Siwash Rock, Vancouver (lower right).


GUGGENHEIM

Projections have widely been used for creating artistic installations as interventions in physical and social space. Artists discard barricades and insert themselves into streets, laneways, alleys and shopping centers [11]. For example Sinatti [12] has used a 40" touch screen display to paint and project on huge surfaces, and Wodiczko [13] has created large-scale video projections of politically charged images on architectural façades and monuments worldwide. Some projection-based installations involve different interactive techniques. For example GRL's 'Laser Tag' [14] tracks a green laser pointer across the face of a building, generates graphics based on the laser pointer's position and project them back onto the building. Tagtool [15] is a VJ tool and drawing instrument that utilizes a graphics tablet and controllers to create animated graphics for video projections.

A particular artistic movement that builds heavily on video projections is "guerilla art" known through artists like Banksy [16]. It is closely related to urban street art, a subtopic of the emerging research field of urban computing, which studies the integration of computing technologies into everyday urban settings and lifestyles [17]. Due to their complex ownership and legal ramifications, urban settings are challenging places for experimentation and deployment, as the installation and operation of an application or an art piece typically require permissions from many stakeholders. Thus it is no surprise that the inherent freedom of playful arenas combined with intimate ubiquitous technologies such as video projection has led to a new breed of guerrilla performances [18]. For example, Digital Fringes's Mobile Projection Unit [19] supports guerrilla art by providing a car, a projector, and batteries to various Melbourne "pixelists". The painter, architect and sculptor Hundertwasser [20] is known for expressing his artistic vision in pictorial art on facades.

2. THE MOBISPRAY ART TOOL

SYSTEM COMPONENTS

MobiSpray is a simple client-server application comprised of three components (Figure 4, left): a mobile drawing client, a simple drawing 'server' executing on a PC, and a video projector for projecting the current drawing onto some surface. The mobile drawing client (Figure 5) is implemented with Python for a S60 [21] Symbian cam-

era phone with a built-in motion sensor for the gesture-controlled pointing mechanism (e.g. Nokia N95). Keyboard keys are used for controlling the drawing tools. The client communicates with the server using the UDP protocol over a WLAN (IEEE 802.11b/g) connection. WLAN provides sufficiently low latencies for real-time interaction and allows communication over much greater distances than Bluetooth.

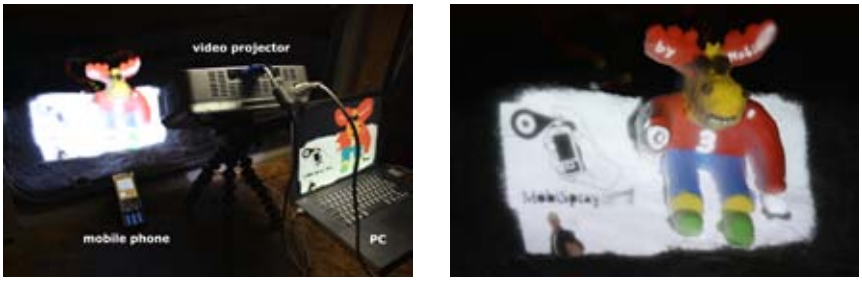

Figure 4 MobiSpray system components (left), Painting on a snow sculpture (right).

The drawing server programmed with Pygame [22] receives drawing commands from the client and renders them accordingly on the drawing canvas displayed on the PC's screen. The video projector projects the screen (i.e. current drawing) onto some surface or backdrop. If no electricity plug is expected to be found in the drawing location, a portable petrol driven generator or a battery with a DC/AC converter can be brought along.

GESTURE-CONTROLLED POINTING MECHANISM WITH A ZOOMABLE NAVIGATOR

The current drawing area is indicated with a black rectangular navigator placed within the drawing canvas corresponding to the white region in Figure 5. The size of the navigator can be changed with a keyboard key, ranging from the full canvas to the minimum size of 100x100 pixels. This way the level of detail can be changed dynamically, from painting on the entire canvas to inserting tiny details such as the character '3' and the word 'by' in Figure 4 (right). The location of the navigator within the canvas is controlled with the phone's navigation key.

The gesture-control of the pointing mechanism is implemented by mapping the phone's motion sensor readings onto x and y coordi-

nates within the navigator in real-time. When the phone is held flat horizontally to the ground, the motion sensor generates the value 0 for both x and y axis and the drawing blob is placed at the centre of the navigator. When the phone is tilted between 0 and 90 degrees to the left/right or forward/backward, the values change incrementally between 0 and -50/+50 in steps of 1, and the blob is moved accordingly from the centre of the navigator towards left/right/upper/lower edge. The two major advantages of this pointing mechanism are that it does not require any calibration before use or any pointing signal receiver such as sensor bar in Wii [23] or camera in GRL's Laser Tag [24].

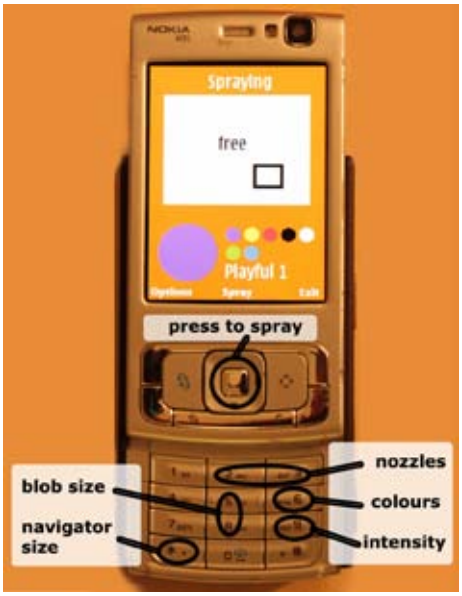

Figure 5 The user interface of the mobile drawing client.

VIRTUAL SPRAYING NOZZLES

The user can choose between four different drawing modes, each representing a virtual spraying nozzle. In the **blob mode,** the nozzle creates a simple color blob on the canvas consisting of a circular element with a color fill. In the **brush mode,** the nozzle creates randomly a multitude of pixels of the same color within a certain radius. In the **image mode,** the nozzle places plain images on the canvas. In the **stencil mode,** the nozzle places stencils on the canvas to spray on.

In the blob and brush mode, the blobs are continuously drawn on the canvas with high frequency. In idle state (phone's navigation key not pressed), previous blobs are overwritten. However, if the user presses the phone's navigation key, which is comparable to pressing the nozzle on a real spray can, previous blobs are no longer overwritten, but by moving the blob by hand gestures a color trace is created (Figure 6).

In the image mode, the image to be placed on the canvas can either be chosen from the image files residing on the phone, or it can be captured with the camera of the phone and sent over to the drawing server. The image can be placed either once or multiple times at any position, such as the MobiSpray logo and photo in Figure 4 (right). Alternatively, the image can be used for image brush painting comparable to the I/O Brush [25]. The user can also spray instantly into the image by switching back to the blob or brush mode (Figure 7).

Figure 6 Painting made with the brush nozzle mode.

In the stencil mode, images and related image masks can be chosen from ready-made files residing on the phone or on the server. The stencil can be moved around with gesture control and is placed at the desired position by pushing the navigation key once. Switching to the brush mode allows spraying onto the stencil's empty areas. The stencil is removed by pressing the hash key.

Figure 7 Painting into photo images.

MULTI-USER MODE

The MobiSpray can also be employed in multi-user mode, which allows collaborative drawing by up to four people simultaneously (Figure 8). The canvas can be split between the multiple users in three different ways: the full canvas accessible by all users (i.e. one user can draw on top of another user), each user with an individual section, or user-specific sections that are partially overlapping.

Figure 8 Multi-user mode.

3. SOME DESIGN AND ARTISTIC ASPECTS OF THE MOBISPRAY

The MobiSpray art tool has been used extensively throughout the world both privately e.g. during guerilla spraying sessions in New York (painting at Guggenheim and New Museum), Sydney (Opera house premises) or London (Houses of parliament and Tate modern) and in many public events such as Urban Screens 2008 festival in Melbourne or the Web 2.0 event in New York. In the following we discuss various design and artistic aspects that have become prominent in the field use. *We enclose some user comments in italic.* They originate from three different sessions where in total 17 people (age 13-70 years) were video interviewed after they had sprayed. They were either passers-by at Melbourne's Federation Square where we had a fixed installation of MobiSpray over several days, or visitors at the London Smartphoneshow evening party where a MobiSpray indoors setup served as a entertainment, or a group of new media enthusiasts at an ad-hoc guerilla spraying occasion in downtown Vancouver.

NATURAL INTERACTION WITH 'TRANSPARENT EQUIPMENT'

"It´s quick to understand what you can do and you can instantly do it." Although MobiSpray's gesture-controlled pointing mechanism may sound clumsy, novice users typically learn it quickly and find painting with the virtual spray can natural. An important aspect of the gesture-controlled interaction is that one can draw by moving the hand without looking at the mobile phone. This demonstrates the concept of 'transparent equipment' [26], in which the user 'sees through' the equipment to the task in hand, such as when you sign your name, the pen is not normally your focus unless it is out of ink.

LIBERATING AND EMPOWERING THE ARTIST

"This is fascinating, now I understand why kids do graffiti."

"I like that it is not premade content to view", "This has been the biggest picture I've ever painted in my life."

MobiSpray liberates and empowers the artist on many complementary levels. With the movable equipment, the artist can effectively start painting anytime anywhere on anything. MobiSpray al-

lows the artist to reach and access the surface of a building, even if (s)he does not own it or have the keys for it. Fences, closed yards or large heights are not a problem, but in fact may present interesting opportunities for guerilla art. MobiSpray allows not only painting on man-made objects such as buildings, but also on nature revealing highly exiting surface patterns (Figure 9). While painting on objects like sculptures has been done for a long time, it has not been possible to paint on nature in such a clean and eco-friendly way as with MobiSpray. When painting on snow sculptures for example (Figure 4), we could even speak of 100% recyclable art. A great advantage of MobiSpray over traditional graffiti and painting techniques is that

Figure 9 Painting exposes the surface patterns on a stone in forest.

the artist can digitally preview the placing of a new blob and with an undo key, the artist can always go back. Thus, with MobiSpray, the artist can visualize future compositions and explore the consequences of bringing a particular composition into existence. Furthermore, the artist can spray exactly the type of art (s)he pleases, for example mixing graphics with photos.

LEGALIZING THE ARTIST

"First I didn't dare to do it because you have some kind of illegal feeling, but then when you do it if feels liberating."

"I like the fact that your painting goes away and you live the moment while you create it, it reminds me of Buddhist sand paintings."

Whereas guerilla actions such as traditional spray can graffiti sometimes cause damage to property or the environment, MobiSpray legalizes the artist since the outcome is an ephemeral digital projection that does no permanent damage to the property. Nevertheless, the question remains of the legal implications, especially in urban spaces. Despite the ephemeral nature of MobiSpray projections, some artists revealed feeling a guilty or naughty upon spraying public buildings. Apparently, the artist should go with the street artist Banksy 's [27] motto: 'It's always easier to get forgiveness than permission'.

EMBODIED INTERACTION WITH PHYSICAL OBJECTS

MobiSpray allows the artist to roam freely (walk, stand, lay) around the target object, far or near in the real physical space, while looking directly at its surface to see how the painting appears in real-time (Figure 10). This puts the artist into a position where (s)he can draw inspiration for a composition directly from the object itself and its context. This is a form of embodied interaction where the artist can interact with physical objects augmented with computational abilities [28].

MENTAL OWNERSHIP OF PHYSICAL OBJECTS

A strong observation with MobiSpray has been that after having painted on a building or some object, the artist feels a sense of ownership of the physical object. By adding something new (the painting) to something already existing (the building or rock), a new

Figure 10 Mobile drawing client allows the artist to roam freely around the object while painting.

whole is created. The experience of the creative process, which results in a deep insight of consequence, contributes to the creation of new meaning and value. This new whole is perceived as one's own creation [29].

AESTHETICS OF THE RESULTING DRAWINGS

The process that leads to the aesthetic outcome often starts with searching and selecting a designated architectural façade or object to serve as the pictorial backdrop. Creating the visual expression not only involves transforming the building or object by projecting ready-made imagery, signs or letters on its surface, but through the very colors (combinations), lines or shapes used in the drawing, producing its aesthetic and emotional response. In this way, through some grace of line, or symmetry of form, or harmony of color, the designated building or object acquires new power to communicate with the artist or viewer. It becomes alive and of value on its own account, just like the trash turning into treasure (Figure 3). As a base for drawing, simple adjustable graphical elements such as a circle (blob or brush) as well as line are used to create the overall visual

form or focus of the compositions. Whereas repetition of symmetric rings (bulls eyes) and splashes give rhythm, logic and balance, their placing is often orientated on the shape of the building or object. The drawing allows to break the patterns of the objects' natural appearance, creating a new whole with its own aesthetic value.

An acquired drawing style might be explained by Parker's [30] claim that the drawing effects, found by chance perhaps in the first instance, would later be striven for consciously. The question is if the MobiSpray tool is given to other people, could they produce something that looked like it was not made with Mobispray by its creators? When an artist builds the tool for him or herself, they adjust that tool to support what they want to express in the manner they want to see it. What is interesting is that while this 'mannerism' is supported by the tool, it is not the tool itself. Results from our field tests show a wide variety of drawing outcomes made by different people using MobiSpray, which indicates that a variety of drawing styles can emerge with this tool.

MULTI-USER AND SPECTATOR VIEW

"This is fascinating, I have never seen something like that before", "We liked the abstract thing, playing with colours."

When employed in the multi-user mode, the artists have great fun together, both collaboratively working towards a common goal and destroying each other's contributions. For example the group in Figure 8 met for the first time at the MobiSpray stand. After a short while of random painting, they started to negotiate and agreed on the themes and colors to draw collaboratively. Furthermore, our experiences from field use underline the role of the spectators in the social setting. People often gather close by, watching and commenting on the work of the artists, and contributing to the social atmosphere by laughing and shouting.

4. FUTURE WORK

As the current version of MobiSpray still needs several hundreds of watts of electricity, we are exploring opportunities to allow a spectator crowd to generate electricity and thus become part of collaborative artwork creation. Furthermore, by building a cluster of MobiS-

pray units with multiple projectors, we aim to paint whole neighborhoods of a city in a Flash mob [31] manner. Other concepts that could be attached to MobiSpray are media activism, urban planning simulation or theatre and music performances. In order to achieve a wider variety in visual styles, we will create additional spraying nozzles, as well as a stencil creation functionality utilizing the phones camera. We are also developing a lightweight implementation based on a battery driven pico-projector for creating small-scale projections.

5. CONCLUSION

MobiSpray combines a personal mobile phone, a PC and a video projector into a novel art tool for creating ubiquitous digital art. Experiences from extensive field use testify in favor of successful design, liberating and empowering the artist to change their surroundings at their own will, in an ephemeral manner. An off-the-shelf mobile phone has proven to be highly attractive as an interface for a virtual spray can, not only because it is personal, ubiquitous and wirelessly connected. It is also a freehand drawing tool for virtual color spraying, an image capturing device and a processing unit for handling digital stencils. Providing a high degree of freedom, it affords the luxury of painting while being able to roam around your targeted object in the real physical space, near or far.

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Jürgen Scheible is a researcher, musician and media artist. During his doctoral studies at the Aalto University School of Art and Design in Helsinki he ran the MobileHub, a prototype development resource for mobile applications with a strong focus on artistic approaches and creative design. He has previously worked for 8 years at Nokia and in 2006 he was a visiting scientist at MIT, Boston, USA. In 2007 and 2009 Scheible was recognized as a Forum Nokia Champion for his driving vision to be a bridge builder between art, engineering and research. He is the author of the book 'Mobile Python – Rapid prototyping of Applications on the Mobile Platform' (Wiley, 2007). Scheible has been giving innovation workshops on rapid mobile application prototyping in academic and professional settings e.g. at Stanford University, MIT, NTU Taiwan, Yahoo and Nokia.

Creating art with mobile phones in public spaces is an emerging form of artistic expression. This dissertation investigates the design of mobile art applications for creating and sharing interactive art experiences in public spaces. It explores new ways of deploying mobile and ubiquitous computing for art making that fosters creativity and community. This is done by developing a series of novel prototype applications, with a focus on multimodal interfaces, that are put into use in authentic environments for validation by real people.

The results of this research inform future design of new forms of artistic and social activity that may eventually become everyday actions of creative expression and exploration.

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