IPCity

Integrated Project on Interaction and Presence in Urban Environments

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Final Prototypes of Interaction Tools

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Table of Content

Abstract

The cross-reality interaction tools research workpackage focuses on support of mixed reality user interface creation, development, and execution which are designed to specifically suppor the four project showcases. As there are no pre-existing standards for mixed reality user interfaces this results in an iterative design, development and testing approach largely drawn from experiences in the field with the various showcase technologies. In partcular addressing aspects such as multiple devices, platforms and cross-media interaction techniques and the need to provide underlying technologies which can support a plethora of potential end-user interaces. As a result this workpackage focuses not only the range of user interface options but also authoring tools that are designed to overcome some of the complexities involved in the development process.

During the final phase of the project no new developments were undertaken, instead emphasis was placed on improving features which were aligned with the project research questions or where a specific issue had an impact on end-user experience.

Intended Audience

This document is intended to all partners of the project, the reviews for the third project's phase, the EU commission and the public.

1 Workpackage Objectives

Success Criteria Phase IV	(1) The tools and services developed within the current working period (a) / since year two (b) / based on existing technology (c) (2) Significant progress in the development of technologies of each major building block (3) Each technology requested by at least two showcases and actually used by at least one showcase (4) Each technology developed is contributing to the overall project objectives (5) Technology used or requested by other projects or third parties and to what extend (6) Submission of at least 5 conference and/or journal papers (at least one for each of the five major building blocks) (7) Identify new technologies developed within the project not available elsewhere
Objectives Phase IV	**MapLens** (augmented maps on mobile devices over paper maps): Further development based on the results received from field trials. **Multi-Touch Display:** Further development based on the results received from field trials. **Mobile Media Collector (MMC):** The development is advancing after the Fall 2008 trials to phase 2, based on trial feedback. Further field tests and trials with new versions conducted during Spring and Fall of 2009. **MMS Entrance**: Further trials integrated to Multi-Touch Display. **ColorTable**: Final development including all the results from the former user workshops, ending with some last trials and a user workshop. **UrbanSketcher:** Further development based on results from further trials and user workshops. **Audio / Video Streaming:** Extending the Device Abstraction Layer (DEVAL) to support audio and video streaming. Designed and developed a audio and video streaming device abstraction **Authoring and Orchestration Interface:** Developing a 3D authoring interface based on Interaction Prototyping and improving upon concepts developed in AuthOr. Further, continued development on Interaction Prototyping (Interactive Bits) visual editor.
Results Phase IV	No new tools have been developed within phase IV (1a). The following tools from phase III have been extended (1b): • **Interaction Prototyping / Authoring**: The interaction

	prototyping language and editor technology development, recently named Interactive Bits, continued based on feedback from the showcases. • Authoring and Orchestration Interface: **AuthOr** development continued based on feedback from the showcases. • **Augmented Map Table**: The augmented map table system was successfully integrated with the ColorTable and UrbanSketcher systems in two workshops as part of collaboration between TUW / TUG / UCAM. • **MapLens** (augmented maps on mobile devices over paper maps) was redesigned and developed further based on the results received from previous field trials in collaboration between HIIT / UOulu / TUG/ Imagination. Two field trials were conducted to test the new features. • **UrbanSketcher** Interface Streamlining: The UrbanSketcher user interface was redesigned and a new 2D interface for laser pointer interaction was developed comprising the most common functionalities. • **Mobile Media Collector (MMC):** Development of the MMC continued following the design in Phase II during 2009. The implementation included new features identified in the Fall 2008 user tests, including usability improvements, and a new Radar view to show nearby location specific stories in the field. Also it is now possible to attach both image and sound files to a single location specific story. • **Multi-Touch Display:** Last years field trial data was analysed thoroughly. Based on the analysis and expert evaluations the interaction design of the new 3D UI was improved. • ColorTable The interface and main interactions were redesigned based on the workshop participants feedback of 2008 and the analysis of DataStream from video, sound recording and the photo documentation. No pre-existing tools have been extended within phase IV (1c). The following tools have been requested by other projects or third parties (5): • The **ColorTable** and the team at TUW was invited for a week to a participatory workshop for urban planning at the department of Informatics/University of Oslo. • The **Interaction Prototyping Tools** have been used by Fraunhofer FIT to develop the Gandhara exhibit at the Bundeskunsthalle in Bonn, Germany. Number of submissions to conference and/or journals (6): 6 full conference papers, 1 workshop papers, 2 posters

2 Review Report Feedback

Based on the feedback of the reviewers we have taken the following actions:

Focussed on developing or improving new features within existing technologies where they are specifically required within showcases or show a clear material benefit to the user experience, such that if they were not implemented their would be a negative impact on the final user trials. As a result no new systems were developed and existing systems were only improved where appropriate.

3 Conceptual Infrastructure Framework for Interaction and Presence Experience

From a technical point of view, enabling presence and experience in mixed reality environments requires a multi-layer approach. Firstly, providing the general infrastructure (hardware and software) and services to realize MR systems. Secondly, the provision of higher-level tools for authoring MR environments and supporting the realization of MR user interfaces. Thirdly, the development of the actual MR application including application-specific features and tools. Figure 1 further clarifies the concept between the various building blocks of MR technology and gives an overview of interconnections between the developed tools and senses and sensations of presence.

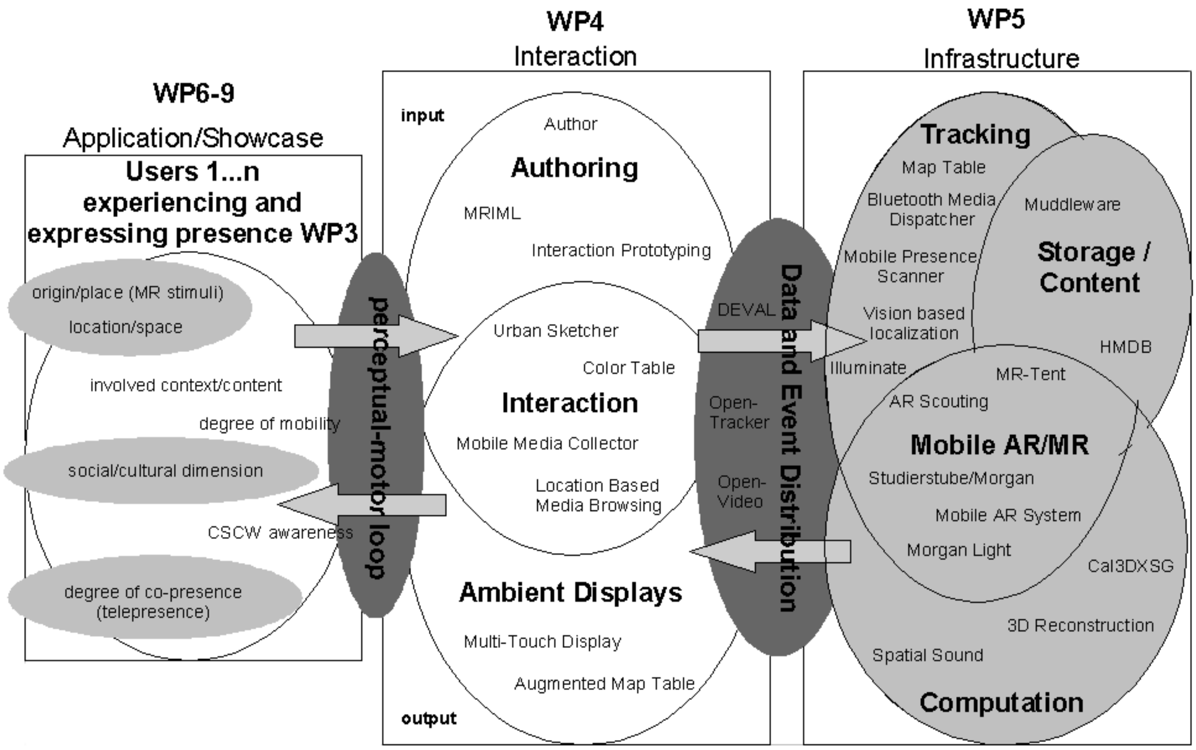


Figure 1: Conceptual Infrastructure Framework Overview

The first section of Figure 1 represents the user in his current context of environment and intention. This is the state of presence or co-presence which is experienced and defines an entry point for mixing reality. The initial situation imposed by a showcase environment implicitly defines suitable characteristics for interface technology. Furthermore the application of software tools and building blocks, which define the infrastructure, allows to dynamically route the exchange of information not only between two users but enables 1-to-n as well as n-to-1 communication, while several modalities supported by the hardware interface can be involved in the communication process.

Interaction between human and machine is possible through these hardware interfaces by connecting senses thus leading to co-presence experiences. Various feedback channels engage individual users and integrate their expressions thus allowing co-construction of presence. The ability to mix the experienced reality at an arbitrary scale is only limited by the capabilities of the underlying infrastructure (Figure 1 right). Therefore integration and the application of open interfaces are essential for large scale collaboration. The cross-reality interaction tools research work package (Figure 1 middle) focuses on support of mixed reality user interface creation, development, and execution. In contrast to traditional user interfaces mixed reality user interfaces are typically not limited to one or two particular devices, but rather use a large variety of individual devices supported by the underlying infrastructure.

Interaction, presence and mixed reality in urban environments are complex phenoma. In contrast to classical research on presence, the phenomena considered in IPCity have collaboration an essential property. From a technical point of view, Mixed Reality was initially described as a continuum by Milgram. Independently, Weiser examined ubiquity, which is obviously important for a project operating in urban space, such as IPCity. These considerations were always kept distinct. The recent publication of Newman et. al.[1] suggests to organize ubiquitous MR applications in a two-dimensions Milgram-Weiser continuum (Figure 2) taking the quantity and density of spatial distribution in to account. This approach is able to better represent configurations where multiple input and/or output devices are interconnected to contribute to MR-systems blurring the border to ubiquitous computing.

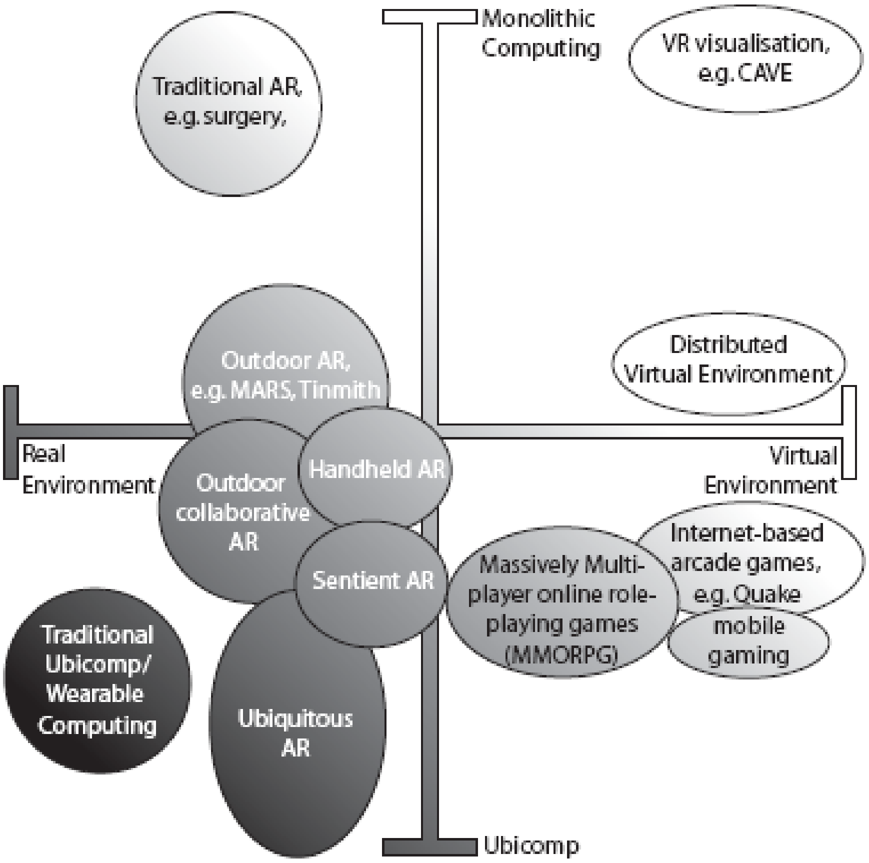


Figure 2 - Milgram-Weiser-Newman Continuum

We felt that even the Milgram-Weiser continuum is not sufficiently expressive when it comes to the representation of co-presence in MR. Among the multiple dimensions of presence that have surfaced in our and related research are at least spatial presence (e.g., perceptual immersion, sense of being there), sensory presence (perceptual realism), engagement (involvement), social presence (co-presence). Consequently Figure 3 suggests a four dimensional continuum enclosing reality, mobility, collaboration and ubiquity. A similar 3-

1 Joseph Newman, Alexander Bornik, Daniel Pustka, Florian Echtler, Manuel Huber, Dieter Schmalstieg, Gudrun Klinker: *Tracking for Distributed Mixed Reality Environments.* Proceedings of IEEE Virtual Reality Workshop on Trends and Issues in Tracking for Virtual Environments, Charlotte NC, USA, March 2007.

dimensional taxonomy, covering immersion, collaboration and mobility, has been proposed by Broll [2] (2002).

The technology we are developing in work packages 4 and 5 represent samples or probes at interesting positions in this very complex conceptual design space. Together they represent the necessary building blocks required by Mobile Mixed Reality applications for users engaging in mixed reality co-presence.

The conceptual design space guides the development and leads to decisions made to address specific aspects out of the design space but also to provide solutions at a possibly large scale. For example, handheld devices have the potential to provide a strong mobile interface, where as stationary technologies have their strength in face to face collaboration. The combination of various types of input devices by interfacing their infrastructures closes the gap between different levels of scale and enriches the overall communication process.

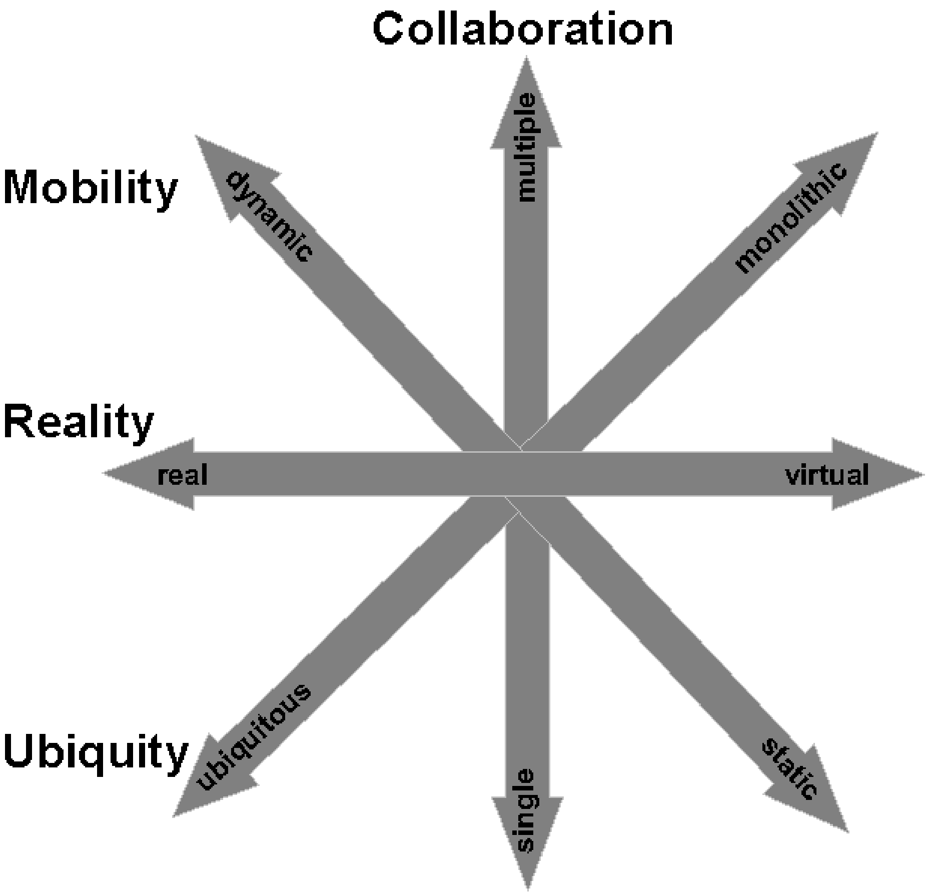


Figure 3 - Multidimensional continuum spanning a design space

The showcases – due to their differences – serve as a good cross section through the design space of Mixed Reality applications. In the spirit of high ubiquity, we favor a building block approach over monolithic solutions. The overall shared vision by the technical work packages WP 4 and WP 5, is to provide all the necessary building blocks required by modern (Mobile) Mixed Reality applications and additionally provide tools to support the design, authoring, direction and evaluation process of its content, user interfaces and interactions. The showcases – due to their differences – serve as a good cross section through the whole area of Mixed Reality applications. In order to concentrate only on those technologies, which

2 Broll, W.: *Collaborating in Mixed Realities*. 3D FORUM, The Journal of Three Dimensional Images Vol. 16, No. 4, (Dec. 2002): 135-140. Also in Proceedings of HC 2002 – the Fifth International Conference on Humans and Computers (Sept. 11 – Sept. 14, 2002), Aizu, Japan, 138-143.

are not unique to only one type of application scenario, we have defined requirements for technologies developed in the technical directed work packages. These requirements for all tools and services are:

- has to be required by at least two showcases,
- must actually be used by at least one showcase,
- must be flexible enough to be used in other showcases and even in other projects.

Since we do not believe that a single tool is able to provide all required aspect of a service, our developed technologies can be overlapping in regards to functionality. The application is hence able to pick the most appropriate set of technologies, which serves its requirements best.

The middle block of **Figure** 1 shows the major building blocks related to Cross-Reality interaction and authoring tools. It has been divided into the following parts:

- Authoring
- Interaction
- Ambient Displays
- Data and Event Distribution

They are visualized as four bubbles inside the middle block providing an overview on to the developed interaction and authoring tools which are needed to create an information space that lives around the users cross reality presence and are described in the next chapter in detail.

4 Cross-Reality Interaction and Authoring Building Blocks

4.1 Authoring

Authoring tools support the developers creating and administrating content and interaction for MR applications and they define one of the major building blocks. We have quite a number of different tools for different tasks of the authoring phase. Due to their diversity all of them provide unique features. *AuthOr* provides functionality for registering an application to a specific area by map augmentation. *Interaction Authoring* is supported by a graphical editor for defining interaction and application behavior. Apart from that, the HMDB can be managed and administrated using a *Web Interface*, while MRIML provides a mark-up language based approach and *Urban Sketcher* allows easy authoring using a drawing package interface metaphor.

4.2 Interaction

The Interaction building block provides new interaction techniques or tools to author, customize and evaluate such techniques for MR applications. In MR applications it is very important to quickly prototype and evaluate new MR interactions, since no standard has yet been defined. The *Interaction Prototyping Tool* including its new graphical editor allows to define interactions and application behavior in a very forward and simple way. On the other hand technologies such as the *ColorTable*, the *Augmented Map Table*, and others provide very powerful customized new interaction methods, which are not only limited to a single application scenario, but can also be used for other applications. Similarly, AuthOr, the Mobile Media Creator use available digital maps in order to visualize application specific information, such as events or locations, and as such allow mobile MR applications to be registered with the application area. *MapLens* provides augmentation functionality for Symbian mobile phones with a camera. The augmentation is optimized for paper maps: when a markerless paper map is viewed through the phone camera, the system analyses and identifies the GPS coordinates of the map area visible on the phone screen. Based on these coordinates, location based media (photos and their metadata) is fetched from HyperMedia Database (HMDB) and presented on the phone screen on top of the map image. This interaction technique, based on augmenting the world seen through mobile phone camera, opens a totally new and interesting application area for mobile phones. Building blocks on mobile devices usable in other tools are the GPS module on location awareness, HMDB Client for uploading media to HMDB using ATOM publishing protocol, as well as HMDB Downloader to fetch media from HMDB using HTTP. All these components have been developed as generic DLLs (Dynamic Link Library) for reuse.

4.3 Ambient Displays

Ambient displays have become more and more popular ways of delivering information in public spaces and are therefore an important part of MR environments. Allowing users to interact directly with the ambient displays gives an easy way to provide people a bi-directional access point to MR applications. *Multi-Touch Wall*, display technology which allows the users to interact with digital content by using their fingers to touch the objects on the screen, now supports also manipulating 3D digital objects.

4.4 Data and Event Distribution

Data and event distribution is another key building block for all MR applications, since these tools provide the means of distributing information between different components; additionally they provide data and device abstraction for easier access to a large variety of heterogeneous interaction devices. DEVAL (DEVice Abstraction Layer) provides such a unified approach without focusing on a specific device class or specific aspects. Our approach is based on an overall device hierarchy, where each abstract interface exposes certain common aspects of a class of devices. Concrete devices are also represented by an interface of their own, which is derived from a number of abstract interfaces, therefore providing device specific functionality. OpenTracker and OpenVideo provide similary functionality but they are restricted – and thus more specialized – to specific device classes, namely tracking devices and video devices respectively. MMS Entrance provides access to different kinds of media, enabling content production from “normal” users using their mobile phones and either MMS or SMS (a new feature implemented recently). MMS Entrance inserts the media with metadata to HMDB, from where media can futher be used by different clients.

5 Year 4 Prototypes

During the final phase of the project the prototypes have been improved and refined based on the detailed workplan months 37-51 (D1.12). In the following document each prototype is described with reference to previous period, followed by an overview of the new research and development, testing and public demonstration and evaluation.

One of the main challenges within the final year of the project was to address the needs of users which were identified during year 3 and the newly formed research questions (See D1.12). This resulted in the emphasis being on improving technologies where there was a clear need from one of these two perspectives. For example within ColorTable user feedback had specifically identified a number of improvements to the design of the table and the objects which were used. While the 3D interface redesign for the CityWall system focused on elements which had been identified as critical to the success of the system within previous user studies such as multiplicity of content, users and gradual discovery based around rich interaction possibilities such as playfulness.

From an authoring perspective the research questions within TimeWarp required the ability to easily create complex experiences by providing the developer with quick easy to use tools. Furthermore there was also a need for user friendly system to be in place in time the summer school. As a result most improvement focused on end-user experience and the support of more complex interactions. Maplens and the MMC development adopted a similar perspective with new features or improvements being made where they were required do support specific aspects of future trials or use within the summer school.

In summary therefore workpackage 4 adopted a highly focused approach to development in the final year and this is documented in the remained of this deliverable.

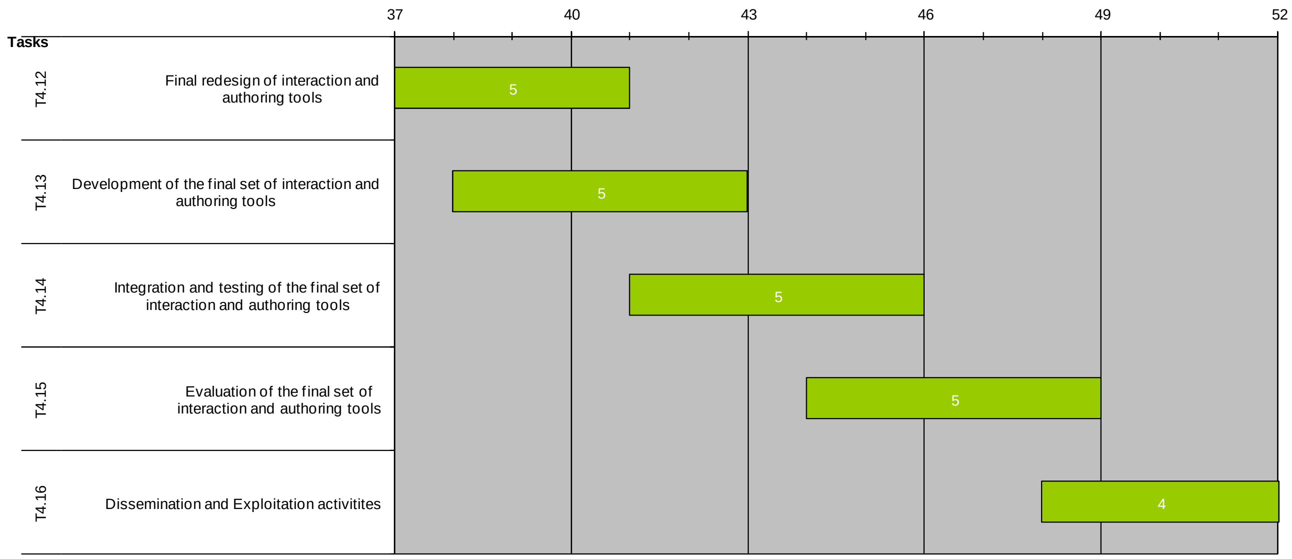


Figure 4 - Detail work plan for Month 37-51.

5.1 Interaction Prototyping

5.1.1 Redesign decisions

In contrast to previous years, significant less re-design decisions were necessary in the last year. Apart from small changes in a few components tests and evaluations showed that the concept matches the user's requirements very well. Therefore, we spent most work in improving and extending already existing features.

5.1.2 Development & research

In the last year much work has been spend to improve the functionality and stability of the behavior engine. Another important topic was the overall performance and usability of the implementation. Several new components have been defined and the remaining missing features have been added to support the user and speed up the process of development.

Improved Visual Interaction Prototyping Editor Overview

Prototyping of interaction techniques and object behavior can be complex and while our first text-based version of interaction prototyping was already very powerful, the user quickly lost the overview within the created text file. By the first version of the visual programming environment we were able to significantly improve the creation of interaction techniques and object behavior using graphical elements that could simply be handled by convenient drag-and-drop mechanisms.

Nevertheless more advanced interaction techniques can easily fill the entire screen making the interaction even in the graphical editor difficult to understand. In order to overcome this problem and improve the overview various new functions were implemented.

Navigator widget

The navigator widget (see Figure 5) shows the network of components of the interaction technique or object behavior in miniature and contains a grey area that displays the viewed part of the edit widget. The user can move the grey area to navigate quickly through large networks or simply click onto a specific point in the navigator widget to directly edit that part of the network in the editing area.

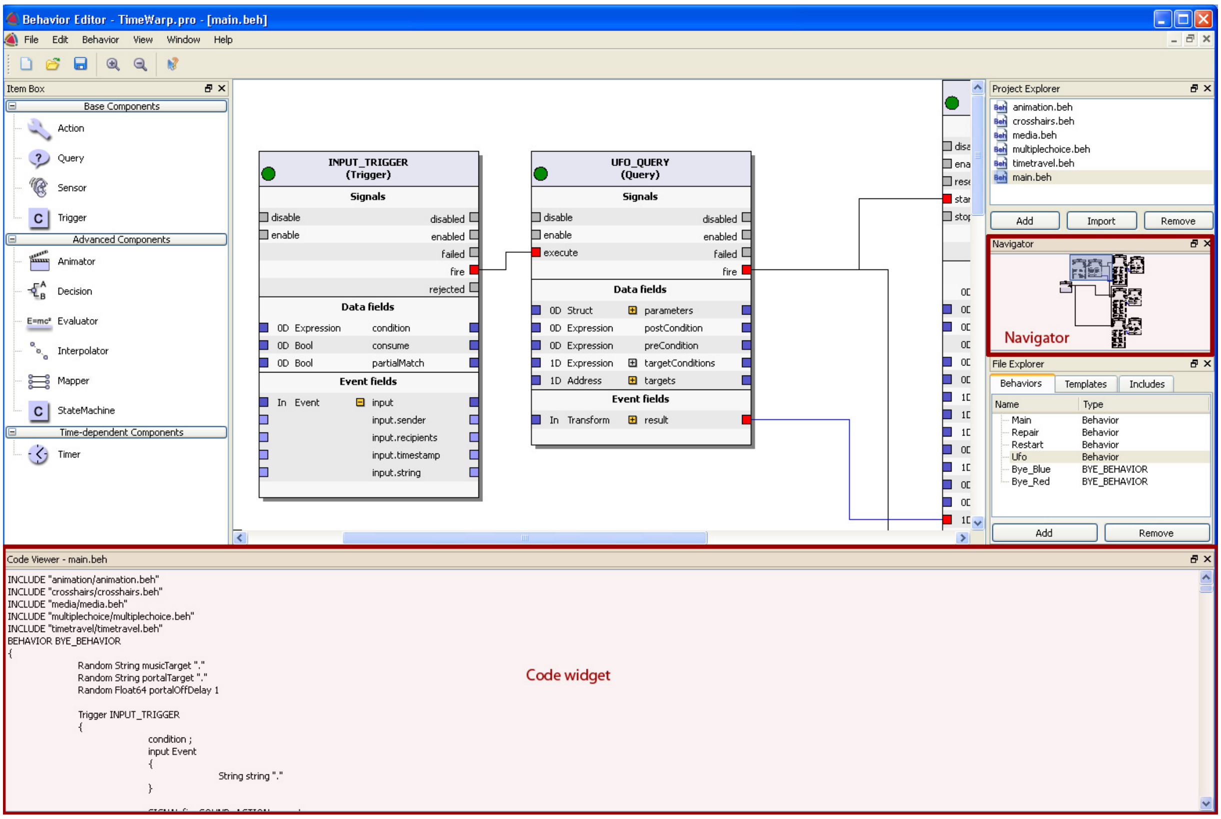


Figure 5 - Simple example of the new network events. The left behavior object sends information from *Computer A* to the right behavior object on *Computer B*.

Advanced view modes

In advanced behavior objects the behavior object or template's purpose is not always obvious at first sight. Usually the best way to understand the functioning is to hide specific parts that might not be relevant. In our current graphical editor we provide two possibilities to do so (see Figure 7):

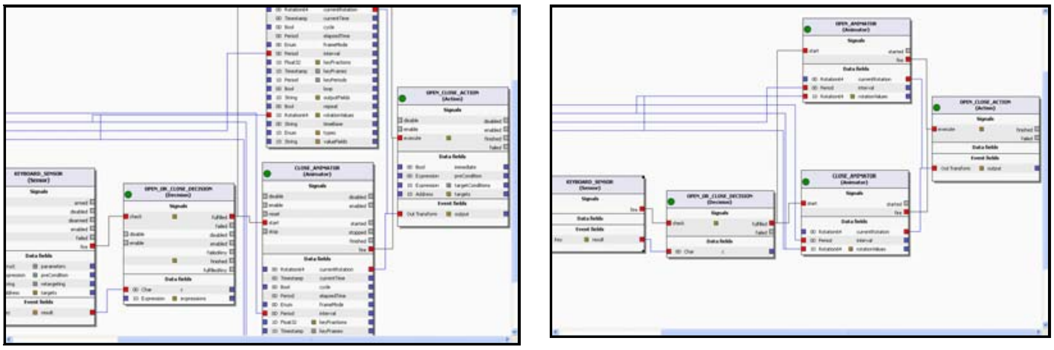
Hiding of either data or signal connections respectively

By hiding e.g. the data connections the control flow between the different components will get more understandable while hiding of the signal connections provides a better understanding of the transferred data.

Edit Mode vs. View mode

Most components have a variety of data and signal fields that can be connected by data or signal connections respectively. Therefore, most components need a lot of screen space and impede to view lots of components at once due to limited screen resolution.

In the current graphical editor we provide two view modes to ease this problem. The "Edit mode" shows every component with all available data and signal field slots. In comparison to the "Edit mode" the "View mode" only shows data and signal field slots that are connected by signal or data connections. This typically reduces the optical appearance of the components drastically and ultimately allows to view more components on the limited screen space.



a) Edit mode b) View mode

Figure 6 - Edit mode vs. view mode

User interfaces

In our first version of the graphical editor we already supported most of the functionality that is covered by the text-based approach. The current version improves the usability aspects of the editor and facilitates the first start by providing helpful information:

Convenient start dialog

While the first version confronted the user with an empty project when creating a new project, the current version offers the possibility to directly create and name a behavior file with a behavior object or template respectively. In this way the editing process is speed up and the start with the graphical editing environment is simplified (see Figure 7).

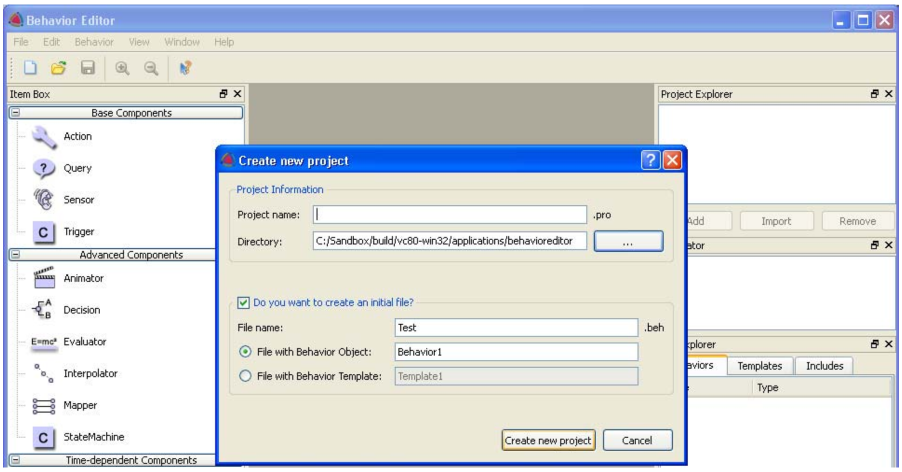


Figure 7 - Improved user interface for new project

Improved component properties

Many components have a wide variety of variables that can be addressed and are therefore powerful but probably hardly understandable on first use. In order to simplify the access to the concept, the variety of data fields was divided into standard data fields, containing the most essential - nearly always used - fields and extended data fields covering the rest of the data fields (see Figure 8). Thus, an inexperienced user will see all essential data fields first, avoiding that the user gets overstrained. The specification of the field types is realized via an XML file that can easily be adjusted by the user.

Furthermore, the “active”- field that is provided by every component indicating the current active-state of the component is now visualized directly in the components appearance and can be changed via the button on the component appearance.

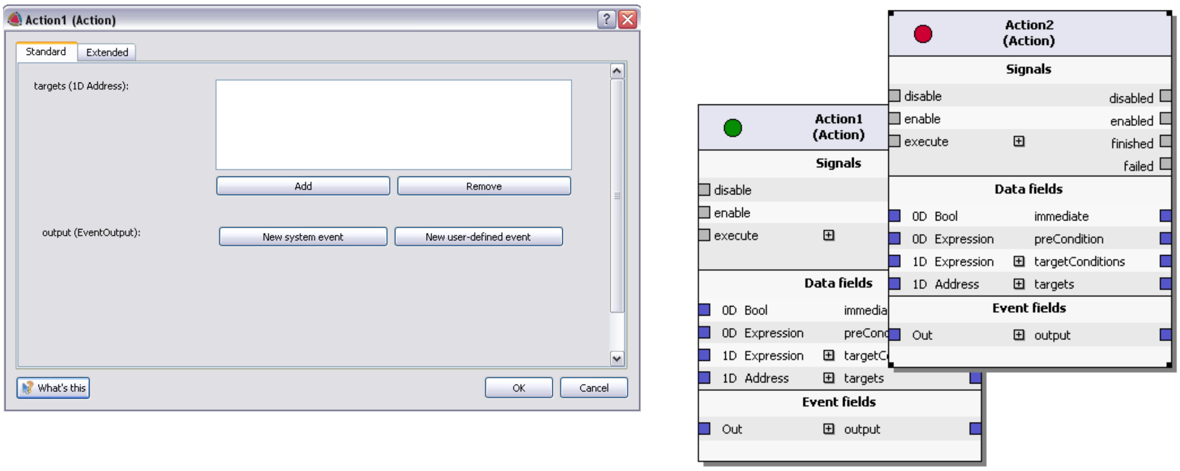


Figure 8 - New properties dialog and active-button

Icon bars and menus

The graphical editing environment was provided with regular icon bars, as well as shortcuts to quickly perform recurring tasks.

Context-based information

So far the correct use of the predefined fields had to be learnt either by trial-and-error principle or by cumbersome uplooking in the “Interactive Bits”-specification. Therefore, a context-based help was integrated that provides further information on each predefined data field or component. The help information is stored in an XML file that can easily be extended.

Debugging functionality

Debugging of complex user interfaces and applications, involving large networks of components with various data and signal connections, was so far difficult as there was no way to understand or simulate the execution of the developed files in the AR/VR viewer Marvin.

In order to reduce the effort of debugging behavior files, we implemented a debugging functionality allowing to observe the values of data fields in the viewer during runtime (see Figure 6, right side). Every data field can be accessed by this debugging mechanism. In the graphical editor the user can simply check a data field in the debug tab of the properties dialog of a component (see Figure 6 left side) to display debug information in the output log of the viewer.

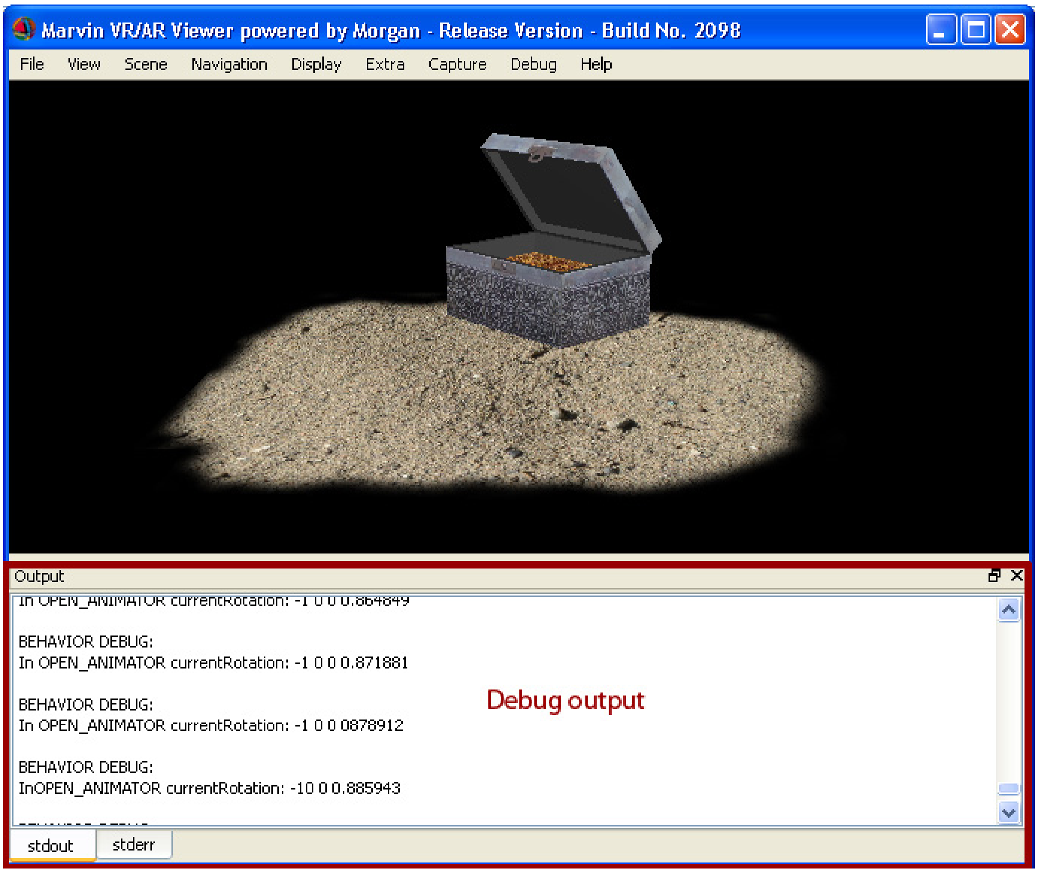


Figure 9 - Checking of debug fields in properties dialog in graphical editor

Code viewer

The code viewer is a new dock widget of the graphical editor showing the generated behavior file text (see Figure 1). In that way users with a strong programming background can learn how the behavior files are modeled in text files and can decide if they prefer to use text based or visual programming. It is possible to copy text segments from the code widget into an existing behavior file and therefore existing behavior objects can be extended by this mechanism as well.

Implementation

The behavior engine is entirely written in C++ and has primarily been implemented for use within the AR/VR Morgan framework. For that reason it is partially based on Morgan support components. It is available on all Morgan platforms including mobile devices such as PDAs and smart phones (based on Windows Mobile). The implementation however can easily be used within 3rd party software as well. We foster this by a unified interface, which realizes access to and from all external components.

5.1.3 Related Work

Abawi, D.F., Dörner, R., Haller, M., Zauner, J. *Efficient mixed reality application development*. Proceedings of Visual Media Production, 2004. (CVMP). 1st European Conference on 15-16 March 2004 Page(s):289 – 294, 2004.

Abrams, M., Phanouriou, C., Batongbacal, A.L., Williams, S.M., and Shuster, J.E. *UIML: An Appliance-Independent XML User Interface Language*. In Proc. of the Eighth International World Wide Web Conference, Elsevier, Toronto, Canada, pp. 1695-1708, 1999.

Bowman, D., Kruijff, E., LaViola, J., and Poupyrev, I. *3D User Interfaces: Theory and Practice*, Addison-Wesley, Boston, 2004.

Burrows, T., and England, D. *YABLE—yet another behaviour language*. In Proc. of the Tenth international Conference on 3D Web Technology (Bangor, United Kingdom, March 29 - April 01, 2005). Web3D '05. ACM, New York, NY, 65-73, 2005.

Dachselt, R., and Rukzio, E. *Behavior3D: an XML-based framework for 3D graphics behavior*. In Proc. of the Eighth international Conference on 3D Web Technology (Saint Malo, France, March 09 - 12, 2003). Web3D '03. ACM, New York, NY, 101-ff, 2003.

Dragicevic, P., and Fekete, J.D. *Input Device Selection and-Interaction Configuration with ICON*. In Proc. IHM-HCI 2001. Frontiers, Lille, France, Springer Verlag. 543-448, 2001.

Figueroa, P., Green, M., and Hoover, H.J. *InTml: a description language for VR applications*. In Proc. of the Seventh international Conference on 3D Web Technology (Tempe, Arizona, USA, February 24 - 28, 2002). Web3D '02. ACM, New York, NY, 53-58, 2002.

Lanier, J., Grimaud, J.J, Harvill, Y., Lasko-Harvill, A., Blanchard, C., Oberman, M., and Teitel, M.. *Method and system for generating objects for a multi-person virtual world using data flow networks*. United States Patent 5588139, 2003.

Ledermann, F., and Schmalstieg, D. *APRIL A High-Level Framework for Creating Augmented Reality Presentations*. In Proc. of the 2005 IEEE Conference 2005 on Virtual Reality (March 12 - 16, 2005). VR. IEEE Computer Society, Washington, DC, 187-194, 2005.

Lee, G.A, Nelles, C., Billinghurst, M., and Kim, G.J. *Immersive Authoring of Tangible Augmented Reality Applications*. In Proc. of the Third IEEE and ACM international Symposium on Mixed and Augmented Reality (Ismar'04) - Volume 00 (November 02 - 05, 2004). ISMAR. IEEE Computer Society, Washington, DC, 172-181, 2004.

MacIntyre, B., Gandy, M., Dow, S., and Bolter, J.D. *DART: a toolkit for rapid design exploration of augmented reality experiences*. In Proc. of the 17th Annual ACM Symposium on User interface Software and Technology (Santa Fe, NM, USA, October 24 - 27, 2004). UIST '04. ACM, New York, NY, 197-206, 2004.

Olwal, A., and Feiner, S. *Unit: modular development of distributed interaction techniques for highly interactive user interfaces*. In Proc. of the 2nd international Conference on Computer Graphics and interactive Techniques in Australasia and South East Asia (Singapore, June 15 - 18, 2004). S. N. Spencer, Ed. GRAPHITE '04. ACM, New York, NY, 131-138, 2004.

Reitmayr, G., and Schmalstieg, D. *An open software architecture for virtual reality interaction*. In Proc. of the ACM Symposium on Virtual Reality Software and Technology (Banff, Alberta, Canada, November 15 - 17, 2001). VRST '01. ACM, New York, NY, 47-54, 2001.

Sandor, C., and Reicher, T. *CUIML: A Language for the Generation of Multimodal Human-Computer Interfaces*. In Proc. of the European UIML Conference, 2001.

Vitzthum, A. 2006. SSIML/Components: a visual language for the abstract specification of 3D components. In Proceedings of the Eleventh international Conference on 3D Web Technology (Columbia, Maryland, April 18 - 21, 2006). Web3D '06. ACM, New York, NY, 143-151.

Zauner, J, and Haller, M. *Authoring of Mixed Reality Applications, Including Multi-Marker Calibration for Mobile Device*. In Proc. of 10th Eurographics Symposium on Virtual Environments (EGVE 2004), pp. 87-90, 2004.

5.1.4 Testing and public demonstration

The Interaction Prototyping has been integrated in the WP8 (TimeWarp) showcase. The entire game logic has been build with Interactive Bits interaction prototyping language and was tested intensively.

There is also ongoing interest in the WP9 showcases. Parts of the user interface logic may build on the Interactive Bits interaction prototyping language.

5.1.5 Evaluation

No formal evaluation has been conducted yet. However, informal evaluations with users based on participatory design paradigm have been conducted. The direct user feedback has been used to extended the Interactive Bits interaction prototyping language as well as to provide improvements to the Interactive Bits interaction prototyping language visual programming editor.

5.1.6 Specification

Hardware and OS	Windows XP
Software	Morgan AR/VR Framework
Core Features	Universal tool for realizing • interaction prototypes, • MR user interfaces, • virtual devices, and • whole MR applications. Based on • universal interaction components • template mechanisms • graphical programming environment
Status	Extended prototype
Intended users	Showcase developers, MR developers, MR students
Showcases	TimeWarp (WP8), City Tales (WP9)
Relevance beyond project	The tool is intended for use beyond the scope of this project. It will be used in the EXPLOAR project funded by the EC through its Life-Long-Learning initiative.

5.2 ColorTable

The ColorTable is a toolset for MR-based planning on site. The main ambition is to support collaborative working scenarios by providing tangible interaction possibilities.

The mixed reality and interaction tools that are developed in year 4 are based on the prototypes of year 3. Intensive work has been done to more integrate the different components into understandable places and further simplify the workflow. To achieve this it was necessary to plan and construct a partly new real physical table. The interaction tools of the two prototypes were developed for the urban renewal workshops in 6.

The system of the ColorTable includes different tangible interaction modules that may be used independently. The modules of the year 4 are the new configuration area (RFID interface), the new content and command cards with RFID tags, the minimized barcode interface, the rotating viewpoint and the billboard sketcher.

5.2.1 Redesign decisions

Feedback and analyzing the workshops of the years 1, 2 and 3 exposed the ColorTable once more to further design decisions and development. In the preparation phase for the workshops in 2009 especially two main interaction issues needed redesign: assigning content, placing and manipulating connections.

5.2.2 Workspace and workflow organization

The high number of interaction modes of the ColorTable stressed the importance of organizing the workspace once more. All the material and devices needed should be within reach but not in the way. We resolved these users' problems within tow major design decisions:

1. Developing a more intuitive interaction for assigning content: Using RFID readers mounted underneath the new wooden extensions of the tabletop and RFID tags at the backside of the command and content cards (see Figure 10).

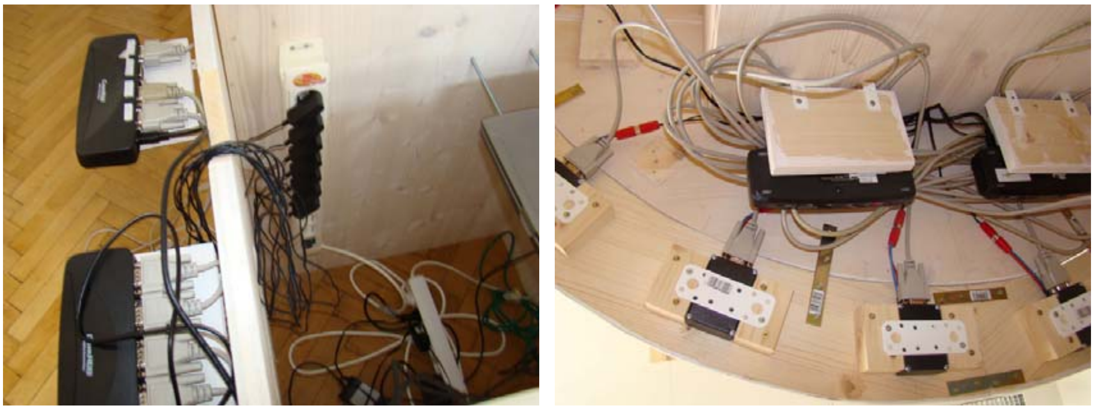


Figure 10 – Developing a better solution for the workflow - assigning content with RFID readers and tags

2. Reorganizing the tabletop: Working on two spatial separated levels: Tabletop with map and configuration area as extension on the highest level; wooden round bar on lower level for free tokens, barcode readers, barcode tables and remote control of the mobile scout (see Figure 11).

Figure 11 – Developing a RFID configuration area and two spatial separated wooden extensions

5.2.3 The new physical ColorTable with Configuration Area

To simplify the set up inside and around the ColorTable and to achieve a supporting workspace we redesigned and reconstructed the physical ColorTable. The new physical table is wooden and consists of (see Figure 12):

- One wooden round tabletop (diameter: 120 cm) extended on the front half-round with a wooden bar at the same level (12 cm).
- Underneath a prefixed wooden frame to predefine the exact place for the mouse (rotating viewpoint) and a prefixed metal frames for the 7 RFID readers (configuration area).
- A second wooden half-round extension mounted 15cm lower at the backside of the ColorTable for all the physical objects needed to work with the ColorTable.
- Two wooden bars mounted at the ColorTable foot to provide stable places for the 2 RFID distributors.
- Three metal sticks inside to provide a place for the ColorTable server.

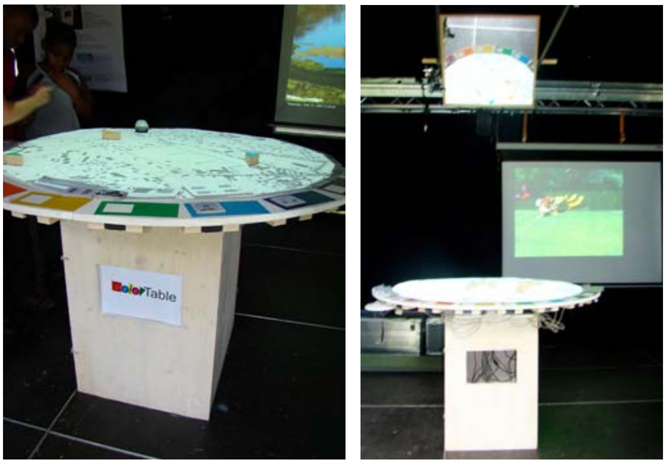


Figure 12 - Physical ColorTable in the MR tent with mirror for projection and panorama view

The new configuration area was designed to assign content in a more intuitive way. Therefore the wooden extension was parted into 7 different color zones communicating the 7 used tracking colors (the 8th tracking color – pink – was used for the special tokens – see Token paragraph). Each color zone consists of a plain window with the same size as the command and content cards and a colored area next to it for placing used cards (see Figure 13).

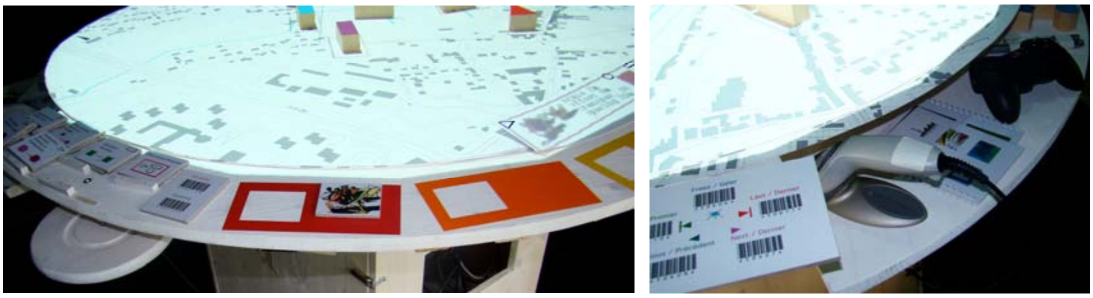


Figure 13 – Configuration area with viewpoint wheel, command cards, RFID color zones, barcode tray, barcode reader and remote control

The ColorTable provides place inside for :

- Server
- Hardware of viewpoint rotator

- USB and serial Hubs
- Hardware for RFID readers
- Related cables

5.2.4 Redesigning the color objects

Due to the trials and user workshops we took part, the team at TUW decided to reduce the physical objects and make a new concept for the tokens according to the new configuration area.

Tokens

The tokens come in seven different colors and three shapes (triangle, rectangle, circle). We redesigned the tokens once more to meet user feedback. To foster tactile guidance we used mainly wood. The tokens are formally split into different graspable object to give some fast hint for the use and generic category of content (circle = ground texture, rectangle = connection, triangle = object). The tracking color itself is attached to and represents a specific content (see Figure14).

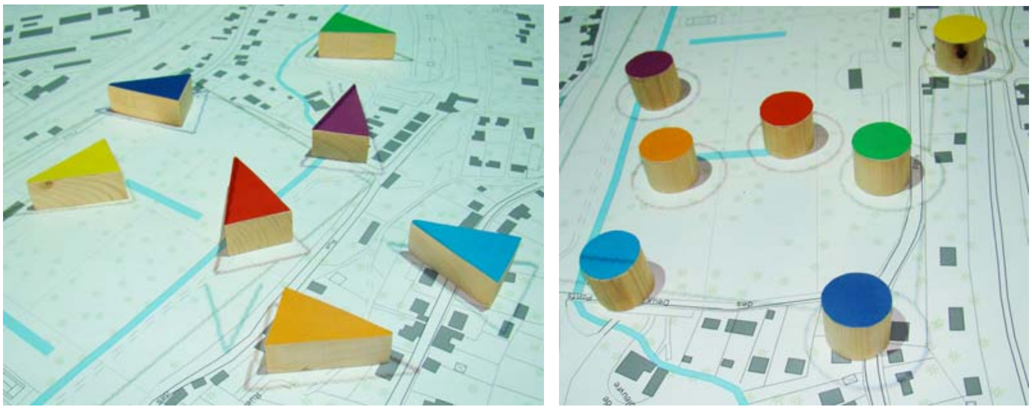


Figure 14 - Different material and forms – triangles and round tokens

One special color (pink) is used for special objects as eraser or moving the point of view, and is not available for arbitrary content assignments (see Figure 15).

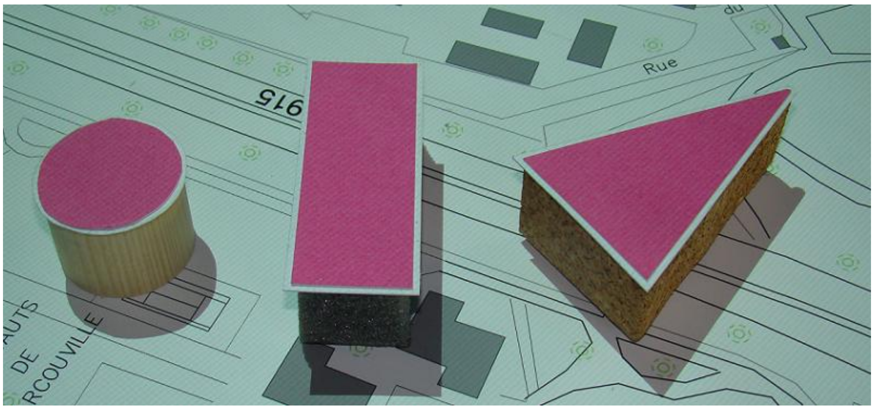


Figure 15 - The different shapes as well for the special tokens. Notice the different material features for eraser (rectangle) and point of view (triangle).

A special token was needed to communicate the interaction possibilities with the sound. When placing objects a default sound is beginning. All the sounds in a scene together create a sounds cape. The sounds cape can be explored by activating a different mode. The most popular is the hearing position: it can be set by placing the pink triangular token shown above, defining the virtual listener's position and orientation.

5.2.5 Configuration and assignment area

In our latest prototype, we re-designed these different components and introduced the RFID board to associate and modify content. This modification modified the chain of actions, which are now: Selecting content at the content board, selecting an unused token, assigning the content to the token color by placing the card on the RFID spot, placing the token on the tabletop and optional changing the content attributes (see). The info area is now shown directly on the surface of the table, next to the RFID board. This modification shortened the chains of actions, decreased the number of objects and devices needed for interaction and integrated some of the elements in one common space (see Figure 16).

Figure 16 - Re-designed chain of actions to add an object to the scene: Selecting content (a), selecting a token, assigning the content (b) and placing the token (c).

Instead of the ColorSeclector and Barcode interface we switched to RFID technology for content assignment. This reduced the number of Barcodes drastically (to a minimum for some other operations), and improved overall intuitivity and clarity of the system.

Figure 17 - The Assignment-Area is used to assign content to the different colors, as well as manipulate attributes.

Most of the content needs to be assigned to a specific color before it can be used. The content is available as physical content cards, that the participants can browse through and finally, after making their decision, place on the field with the desired color. While the color can be chosen freely the type of content automatically bounds it to a determined shape. This shape is also printed on every content card as a helpful hint (see Figure 17).

5.2.6 Flows and Connections

Placing two rectangles of the same color results in a connection that can be also curved by rotating the rectangular tokens on the endpoints. The logic of the flows populating the streets and paths was heavily improved and now different content can be assigned varying in texture, traffic type and density of different connections. The underlying parametric curve is the cubic Bezier (see Figure 18).

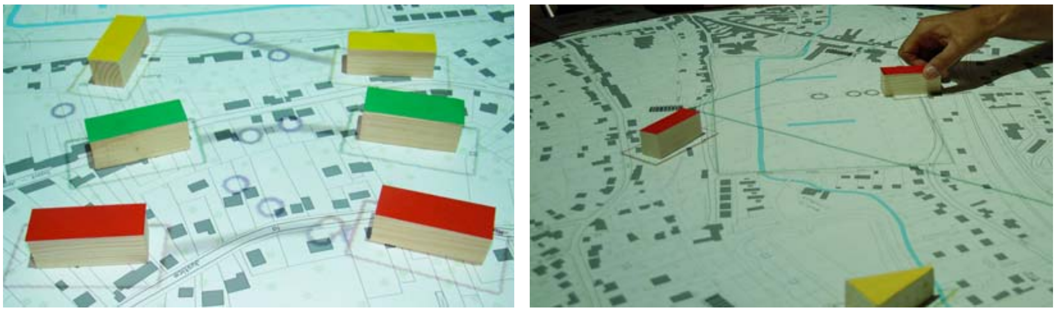


Figure 18 – Curved connections can be placed - Flows automatically start as soon as streets are in the scene

5.2.7 Cards

For the new ColorTable we invented a new category of cards: we introduced the command cards situated directly at the configuration area in addition to the content (displayed at the white board).

Command Cards

While the broad majority of the cards represent different content that can be assigned to the tangible objects, some of the cards are command cards to manipulate content that has already been assigned. Placing one of the cards on the color to be manipulated can change following attributes:

- Size
- Offset (distance from ground, for flying objects)
- Gap (determines the distance between objects in case of making a line)
- Color overlay

The manipulations only apply to billboards and 3d objects (triangular tokens).

For size, offset and gap there are increase and decrease cards. All the attributes-cards work incrementally. (E.g.: “Scale increase” increases the object by a couple of meters every second, until the card is removed from the area)

Information Request

One special command card is the Information Request card: Instead of the Info Screen we display information about the different colors and associations directly on the table now. The display switches automatically to the color changed as last, however information about a color and the assigned content (for all shapes: triangle, rectangle, circle) can be also requested manually by placing the dedicated: content request card on one of the color fields.

5.2.8 Additional redesigned Interaction Modes

Results of former trials and user workshops have shown the need of additional interaction modes. Therefore the workshops in 2008 were used to try out the new developed interaction modes.

Defining Use – ground textures

We redesigned placing and working with ground texture: we replaced the former ground texture solution based on the Voronoi algorithms, which seemed too confusing and inflexible. In the new interaction mode areas that are enclosed by connections can be filled with ground textures (grass, stone, water etc.) by simply placing a circular token in the area on the map.

Working with 3D lines

We redesigned the 3D lines once more to provide a quick way of multiplying single objects. Users have to place two triangles of the same color to create multiple similar objects. The distance and number of the objects in between two triangles can be manipulated by a barcode on a command card (see Figure 19).

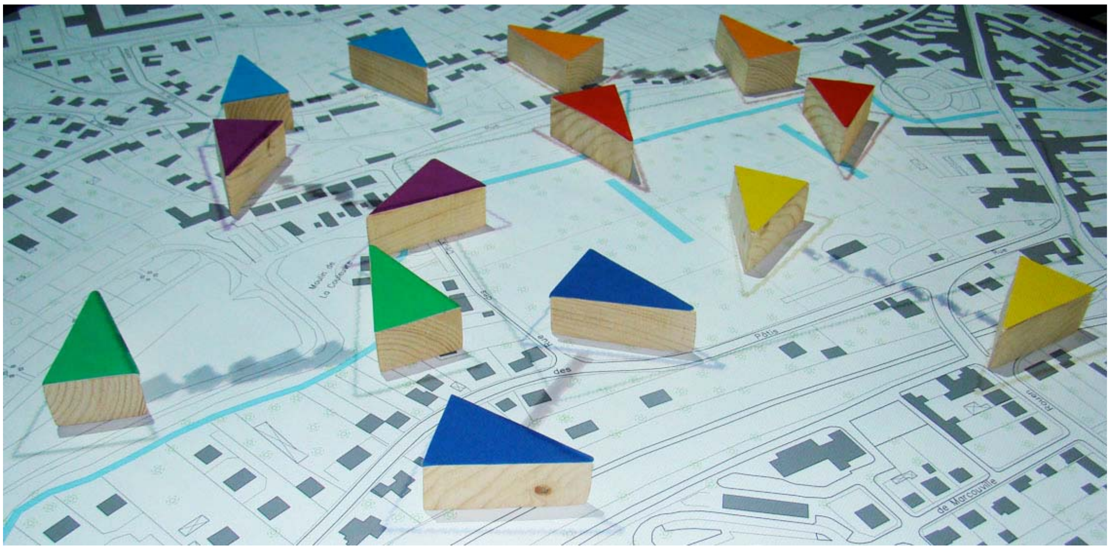


Figure 19 – Placing 3D lines

5.2.9 Maps and Viewpoints

Physical paper-maps of different scales and foci can be placed on the table surface and registered with a barcode. Additionally the available panorama positions are marked on each map and equipped with a barcode, so the participants can switch between them smoothly. All photo-realistic panoramic backgrounds also include depth information for handling occlusions properly. A rotatable wheel allows to rotate the field of view or alternatively to zoom in and out.

3d Objects and Billboards (triangular tokens)

While 3d geometries can be rotated arbitrarily along the vertical axis (by rotating the token) and can be used as houses and building blocks, the 2d billboards are rectangular images (with optional transparent regions) that always face the observer (trees, flowers,..). Silmilarly as in case of the streets placing to identical triangles, results in a line of objects of the associated type (alley with trees).

Paper Sketching

We re-implemented a tool allowing users to add their own paper sketches to the Hypermedia Database in a most simple way. A camera grabs hand-drawn sketches and feeds them into our Media-Database. Content created in this way can be assigned to the tangible tokens in the same way as our pre-prepared content and used in the scene. The sketcher provides means to create new billboards by drawing with conventional on sheets of paper. The billboard sketcher (see Figure 20) consists of…

- One wooden plate with a defined black area for placing the sketches
- One mounted Logitec web cam to capture the sketches
- A barcodes to choose the size and sending it to HMDB

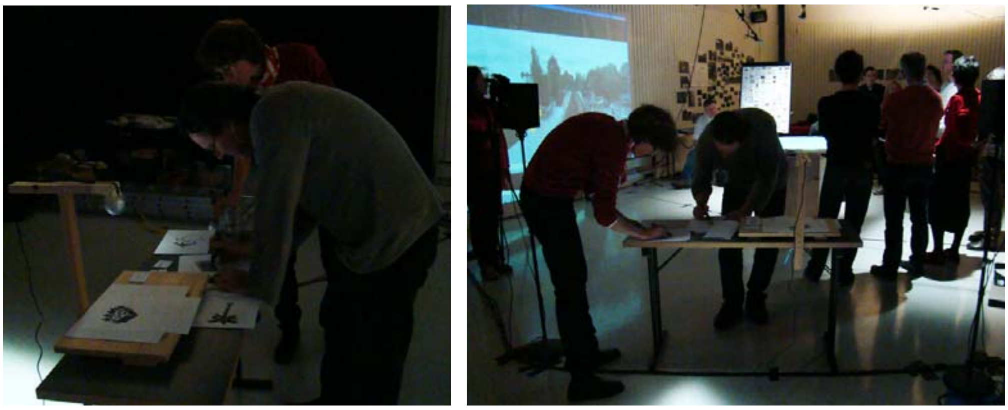


Figure 20 - Adding paper sketches to the HMDB with the billboard sketcher.

Sketching (please see chapter Urban-Sketcher)

Users can sketch directly on top of the projection and also on the 3d objects placed in the scene. This is done with the Urban-Sketcher that supports several painting paradigms. Users can select colors from a palette and choose between different painting-tools (pencil, brush, airbrush).

History Application

The history application is controlled by several barcodes and allows freezing the composed arrangement at any time and later to freely browse through all saved states. The saving works incrementally, so users can save a scene, remove the tokens from the table and then assign and add new content to the existing frozen scene.

Height Map

For the final workshop in Oslo we worked on a specific problem of the panorama view: Since the virtual floor was always flat, it was difficult and in some cases impossible to align it with the panorama background, based on real photographs, in a satisfying way. A gray-scale topological height-map of the area solves this problem by assigning each coordinate also height information that is taken into account for the rendering of the 3d view.

5.2.10 Implications for Interaction Design – final reflection

The material artifacts we have designed for the ColorTable and the physical ColorTable itself take a key role for the interaction. We made use of different materials (wood, cork, cardboard) to distinguish the different types of tokens and physical objects. The last prototype fosters the visual and haptic revisable difference. Some of the re-design we undertook simplified the use of the table and the objects. The design decisions made throughout the last years have been evaluated within the workshops with the users and shown as appropriate for a simplified set up, accessible interaction modes and as a whole a better use.

Important issues and lessons learned for further development are:

- Further simplify the workflow (e.g.: participants often place content cards directly on the table). Simplifying the interface and the interactive objects, especially reducing the additional devices and objects around – creating a clear environment – was one of the biggest challenges for the design and would have to be redone radically.
- Further develop possibilities for the user to annotate and use user generated content (visuals and sounds) in a simple and intuitive way (e.g.: placing a mobile on the table to assign a specific sound)
- Further develop the idea of basic tokens forms to give a visual and haptic guidance and clues for usage as we found product design to be most needed in the area of complex user interfaces.

- Intensify the potentials of materiality: investigate the roles of materiality and physicality to provide a deeper understanding of embodied use and interaction.
- Investigate and further analyze the use of space and body configurations as they give a profound understanding of people's interaction space and collaboration as well as awareness of the real site.

The main interaction research questions therefore are:

- How can we widen the focus of materiality, physicality and spatiality to expand the notion of interaction design?
    - How can we include the challenges of the real site more in the development of the research prototype and interaction modes of the TUI?
    - How can we further optimize physical interaction for users? How can tokens, physical objects and the ColorTable provide visual and tactile guidance?
- How can users understand the workflow and use the interaction possibilities?
    - Are the users able to fully use the application and understand the relation between importing content (magnetic barcode, barcode trays), the basic tokens and the tracking color tokens?
    - Are the users able to understand and fully use the various views (panorama, see through, sound view, mobile scout)?

Some core technologies from the ColorTable and their interaction effects – short overview:

Used Technology	Short Description	Constraint - Interaction Design (from user feedback)
Color Tracking (Aalborg)	A camera above the table captures the picture of the surface with the tokens in different shapes and colors, and extracts their colors, shapes, positions and orientations.	• Size of token (too big) • Instability of tracking (very careful and slow interactions) • Fixed colors – no change possible
HMDB (Helsinki)	Holds the majority of the used content data (panoramas, billboards, 3d objects, textures etc.).	• Users do not understand the design of the underlying database (especially by using the paper sketch) • All content has to be registered manually
Barcode Interface (Vienna)	The barcode interface mainly provides the interaction to change map scales and viewpoints, upload paper sketches and manipulate some attributes.	• Spatial very difficult to place (as they are wired) - Fall down very often • Not collaborative, as only one person can use it
RFID Interface (Vienna)	The seven RFID readers underneath the tabletop surface provide a configuration area to	• Working stable but still evt. a interaction step to much for a majority

	assign and manipulate content.	of users (e.g.: people place content cards directly on the table) • Tags should be hidden inside content cards not fully visible

5.2.11 Related Work

Dant, T. *The Pragmatics of Material Interaction.* Journal of Consumer Culture, Vol. 8, No. 1, 11-33 (2008)

Hornecker, E., Buur, J. *Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction*. Proc. of CHI 2006. Montreal, Canada (full paper). ACM, 437-446, 2006.

Larssen A. T., Robertson T., and Edwards J.. *The feel dimension of technology interaction: exploring tangibles through movement and touch*. In Proc. of TEI '07, pages 271–278. ACM, 2007.

Patten, J., H. Ishii. *A Comparison of Spatial Organization Strategies in Graphical and Tangible User Interfaces*. In: Proceedings of Designing Augmented Reality Environments (DARE) 2000, 41-50, 2000.

Williams, A., Kabisch, E., Dourish, P. *From Interaction to Participation: Configuring Space Through Embodied Interaction. Book UbiComp 2005: Ubiquitous Computing. Volume 3660/2005. Springer Berlin*

5.2.12 Testing and public demonstration

The different interaction modules of the ColorTable have been tested as part of the technology probes developed in WP6. These aim to support groups of urban planners and diverse stakeholders in collaboratively envisioning urban change, using a set of mixed-reality technologies.

The different technology probes have been tested and demonstrated in 4 different workshops during this last phase (phase 4):

- Workshops and demonstration (4 days) in Pontoise/Paris with invited stakeholders and urban planners; June 2009.
- Workshop (1 day) with 8 participants coming from various professions at a master class on tangible interaction at the ECSCW 2009 in Vienna; September 2009.
- Workshops (3 days) with students from various backgrounds at the IPCity summer school; October 2009.
- Invited week in Oslo with workshops and demonstration (3 days) at the department of Informatics/University of Oslo

5.2.13 Specification

Hardware and OS	4x Laptop, 2x Desktop, 2x Projector, 1x Webcam, UrbanSketcher, 2x Flatscreen, 2x Barcode Reader, ColorTable , Windows XP
Software	ColorTable framework, Muddleware, Studierstube, Open Tracker, Tomcat, HMDB
Core Features	Connections: lines and curves, 3x flows, 3D lines, history application: saving and loading, printing,

	sketching;
Status	Gamma prototype
Intended users	Stakeholders and urban planners
Showcases	For all interested showcases and for use in WP6
Relevance beyond project	Development of user interfaces to support the challenge of collaboration, user content preparation and embodied interaction modes.

5.2.14 Publication

Wagner I., Basile M., Ehrenstrasser L., Maquil V., Terrin J., Wagner M. *Supporting the Formation of Cummunities of Practise; Urban Planning in the MR-Tent.* In: C&T 2009.

5.3 MapLens

MapLens is an application for Symbian OS S60 on Nokia N95 phones with camera and GPS. When a paper map is viewed through the phone camera, the system analyses and identifies the GPS coordinates of the map area visible on the phone screen. Based on these coordinates, location based media (photos and their metadata) is fetched from Imagination's server. Markers to access the media by clicking the selected marker showing the thumbnail of the photo are then provided on top of the map image on the phone screen (see Figure 22).

The paper map used with MapLens is an unmodified satellite image (with street overlay) from Google Maps. The phone camera and display are used as a viewer on top of the paper map, which is then augmented with location based data.

Users browse the augmented map by physically panning the phone's camera over it. MapLens overlays the real map with icons that identify the game clues and the users' photos. Users select icons via an on-screen viewfinder frame. One click provides a list of thumbnails for all selected icons, while a further click zooms any desired image to full-screen for closer inspection.

A "you are here" icon shows the position of the user in the map, helping the user to orientate herself against the locative media visible on the augmented paper map. One keyboard shortcut is used to remove excessive data off the screen.

MapLens runs at interactive frame rates of 16-20Hz on the N95. It uses the 3D tracking method described in detail in D5.4 and in Wagner et al. (2009b). It is important to note that once the map is detected, the tracking is extremely robust, even to strong changes in illumination (sunlight) blur, and strong tilts of up to 90°. The tracking supports camera distances from the map between 10cm and 2m, accommodating almost every physical use case.

While the 3D tracking and image augmentation execute directly on the phone for minimal latency, the MapLens system relies on client/server architecture for storing and retrieving the media data. The server provides mobile clients with HTTP access to a geographic information system (GIS), allowing for location-based queries to media and associated metadata (location, date/time, user name, etc.). As the user launches MapLens, a connection to the server is made to download data related to the area on the paper map. The place marks found within are drawn on top of the paper map in correct places. Clients are also able to upload GPS tagged photos to the server using the standard newsfeed (ATOM) protocol.

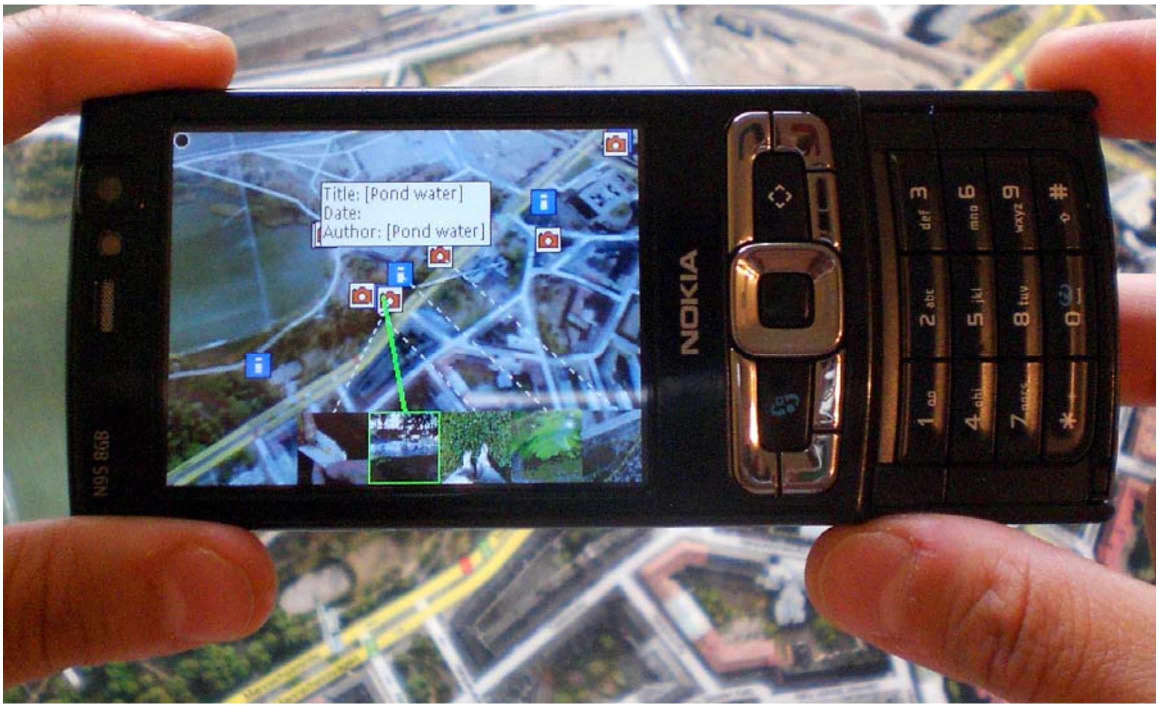


Figure 21 - MapLens in use with a paper map showing multiple thumbnails.

5.3.1 Redesign issues

Based on feedback received from last year's field trials, MapLens was redesigned to have new features listed in Table 1.

Table 1. MapLens old, redesigned and new features.

Feature	**Explanation**
Green circle (you are here)	To ease navigation, a green circle indicating the current location of the user on the map was added.
Selection viewfinder (red square)	This feature had enhanced useability features added (see below)
Icon information (clues)	Icon information: removed extraneous text information, added information on location, and it was made easier to retrievew it with new multiple thumbnails view (see below)
Camera information (photos)	The interface was designed to give more feedback when taking a photo, so user has a cliear understanding when photo is taken and uploaded. Taking of photos was redesigned to use the phone's photo capture button instead of the button 0 that was previously used.
Single Thumbnail online	Viewing single thumbnails online was not redesigned: focusing with the viewfinder reveals the thumbnail and clicking on it enlarges it.
Multiple thumbnails online	This view was totally redesigned: to make it more easier for the users selecting an image from a cluttered view: when a lot of icons are stacked together, clicking a thumbnail does not enlarge the thumbnail right away, but opens a horizontal list of thumbnails of pictures from the same area showing also a line connected to the icon, so user is really aware which icon belongs to what photo. Clicking the thumbnail enlarges the photo.
Multiple thumbnails offline	The multiple thumbnail view described above can be also used in offline mode: the thumbnails stay on the screen and can be interacted with even if you take away the paper map.

Enlarged image (full-screen)	This feature was not redesigned from last year.
Photo countdown	When taking a photo the user is presented a countdown from 3 to 0. At 0 the photo is uploaded. This gives the user the possibility to abort photo uploading and minimizes the risk of accidental photo uploading.
Photo upload (preview)	While showing the photo countdown, user is presented a preview of the photo so she can evaluate if the photo is worth of uploading
Improved tracking	The tracking was reimplemented to provide a more robust and stable user experience. Resulting tracker is 1-2 orders of magnitude faster than naïve approaches towards natural-feature tracking used in earlier system.
Server-side	The server-side was changed from using HMDB to use Imagination's CityTales2 server implementation, which enabled creation of the game area through web interface and improved the performance of the overall system. Using Imagination's system also allowed us to free us from using third party applications shuch as ShoZu and Flickr.

The redesign of the system was done in collaboration with HIIT, TUG and Uoulu.

5.3.2 Related work

Earlier in its evolution, AR was demonstrated as a tool for collocated collaboration in (Billinghurst et al. 1996, Schmalstieg et al., 1998), but the practical value of such "shared space" technology was limited by its stationary nature and high cost per user. The first stand-alone AR application on a mobile device was presented in (Wagner et al. 2003). Since then, AR on handhelds has been explored with different applications, both individual and collaborative (Henrysson et al., 2005, Wagner et al., 2005, Wagner et al. 2006) The sophistication of the camera-based tracking determines what kind of application can be built. Simple motion sensing (Brown & Chalmers, 2003) allows only 2D interaction, while tracking of fiducial markers or natural features allows richer shared space interaction, but has only recently become feasible.

Our interest in using mobile AR with a tangible map is grounded in an interest in working explicitly with a moveable object with well-defined meaning. The rationale is that such a setup allows exploration of the more physical aspects of AR, which are mostly neglected. Our research does not specifically rely on properties of cartography or map navigation, however, it does investigate the handling of mobile phone AR with a physical object carrying complex contextual information in and of itself.

Concerning maps, an ethnographic study of city tourists' practices is presented by Brown & Chalmers (2003), describing how tourists work together in groups and collaborate around maps and guidebooks. The observations however do not detail aspects such as the roles of tourists and the use of singular or multiple maps. Combining paper maps with mobile devices has been previously implemented through simpler means, such as RFID tags (Reilly et al., 2006) or markers and dots on the map (Rohs 2007) Evaluation of these systems has focused on evaluating the impact of visual context (Rohs et al. 2007) and tracking technique (Reilly et al., 2006) on task performance of the individual. However, none of these works consider collaboration and device handling. Evaluating such user interfaces in real settings is difficult as can also be seen by the very few studies that are mostly carried out in laboratory environments. Some studies are aimed at building predictive models (Rohs, 2007, Rohs & Oulasvirta, 2007, Cao et al., 2008, Mehra et al. 2006). Other studies of handheld AR carry out in-laboratory formative evaluations (Henrysson et al. 2005). The work in Schmalstieg (2007) describes one of the first AR group collaborations in a larger indoor space, a museum, but evaluates mostly technical aspects. The observation of outdoor AR users "in the wild" is limited to very few recent reports (Morrisson et al. 2009, Herbst et al. 2008).

In an earlier trial (Morrisson et al. 2009), we compared the use of MapLens to the use of a standard 2D mobile map application in the same location-based game. Our main finding was that AR facilitates place-making by creating a constant need for referencing the physical, allows for ease of bodily configurations for the group, encourages establishment of common ground, and thereby invites discussion, negotiation and public problem-solving. We concluded that the main potential of AR with mobiles and tangible objects lies in their use as a collaborative tool. However, the issue of how much the limited availability of MapLens devices influences the users' behavior was left for future work and is picked up here.

References

Billinghurst, M., Weghorst, S., Furness, T. (1996) Shared Space: An Augmented Reality Interface for Computer Supported Collaborative Work. In Proc. Collaborative Virtual Environments Workshop 1996.

Brown, B., Chalmers, M. Tourism and mobile technology. In Proc. ECSCW 2003, Kluwer Academic Publishers (2003), 335–355.

Cao, X., Li, J., Balakrishnan, R. Peephole pointing: modeling acquisition of dynamically revealed targets. Proc. CHI 2008, ACM Press (2008), 1699–1708.

Henrysson, A., Billinghurst, M., Ollila, M. (2005) Face to Face Collaborative AR on Mobile Phones. In Proc. ISMAR 2005, IEEE Press (2005), 80-89.

Herbst, I., Braun, A.-K., McCall, R., Broll, W. TimeWarp: interactive time travel with a mobile mixed reality game. In Proc. MobileHCI 2008, ACM Press (2008), 235-244.

Mehra, S., Werkhoven, P., Worring, M. Navigating on handheld displays: Dynamic versus static peephole navigation. In Proc. TOCHI 2006, ACM Press (2006).

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmelä, S., Jacucci, G., Reitmayr, G., Näsänen, J., Juustila, A. Like bees around the hive: A comparative study of a mobile augmented reality map. In Proc. CHI 2009, ACM Press (2009), 1889-1898.

Reilly, D., Rodgers, M., Argue, R., Nunes, M., Inkpen, K. Marked-up maps: combining paper maps and electronic information resources. Personal Ubiquitous Computing 10, 4 (2006), 215–226.

Rohs, M. Using Visual Markers for Embodied Interaction in Handheld Augmented Reality Games. In Magerkurth, C, Röcker, C (eds) Concepts and Technologies for Pervasive Games, Shaker Verlag, Aachen, 2007, 207–230.

Rohs, M., Schöning, J., Raubal, M., Essl, G., Kruger, A. Map navigation with mobile devices: virtual versus physical movement with and without visual context. In Proc. ICMI 2007, ACM Press (2007), 146–153.

Rohs, M., Oulasvirta, A. Target acquisition with camera phones when used as magic lenses. In Proc. CHI 2008, ACM Press (2008), 1409-1418.

Schmalstieg, D., Fuhrmann, A., Szalavári, Z., Gervautz M. Studierstube - An Environment for Collaboration in Augmented Reality. In Proc. Collaborative Virtual Environments 1996. Republished in Virtual Reality 3,1 (1998) 37-49.

Schmalstieg, D., Wagner, D. Experiences with Handheld Augmented Reality. In Proc. IEEE International Symposium on Mixed and Augmented Reality, ACM Press (2007), 3-18.

Wagner, D., Schmalstieg, D. First Steps Towards Handheld Augmented Reality. (2003) In Proc. IEEE International Symposium on Wearable Computers 2003, ACM Press (2003,) 127-135.

Wagner, D., Pintaric, T., Ledermann, F., Schmalstieg, D. (2005) Towards Massively Multi-User Augmented Reality on Handheld Devices. In Proc. Pervasive 2005, Springer (2005), 208-219.

Wagner, D., Schmalstieg, D., Billinghurst, M. (2006). Handheld AR for Collaborative Edutainment. In Proc. ICAT 2006, Springer (2006).

Wagner, D., Schmalstieg, D. and Bischof, H. (2009b). Multiple target detection and tracking with guaranteed framerates on mobile phones. To appear: ISMAR 2009.

5.3.3 Testing and public demonstration

The MapLens application was tested extensively in WP7 in two field trials. The trials were designed as location-based treasure hunt games in the Museum of Natural History and the green areas of the city. Unlike in earlier work in which environmental games have been largely narrative-based (Klopfer, 2008) the goal of our game was to connect players with urban nature by giving them a new kind of experience of the city. The goal was to make their connection to urban nature and place to endure beyond the more artificial environment of the game. As such, our aim was to re-position physicality at the core of our players' AR experience by including many artifacts, and designing the game and tasks to remind the participants of their own selves, interacting within the physical world (Merleau-Ponty, 1968).

TUG also has tested MapLens tracking in various conditions. These results have been reported in D5.4 and in more depth in (Wagner et al., 2009).

References

Klopfer, E. (2008). Augmented Learning Research and Design of Mobile Educational Games. MIT Press, Cambridge, MA, USA.

Merleau-Ponty, M. *The visible and the invisible*. Northwestern University Press, Illinois, USA, 1968.

Wagner D., Reitmayr G., Mulloni A., Drummond T., Schmalstieg D., "Real Time Detection and Tracking for Augmented Reality on Mobile Phones," IEEE Transactions on Visualization and Computer Graphics, 18 Aug. 2009. IEEE computer Society Digital Library.

5.3.4 Evaluation

Our field tried conducted in 2009 extend the study of collaboration on mobile phone based AR to a multi-AR and multi-FoR (frame of reference) situation. Having multiple phones and multiple maps on a team created a novel situation not studied in context of AR before. Normally, AR displays content on a unique object that can be shared by a group. Today's mobile phones allow a wider approach. Not only can each user have her own frame of reference (e.g., the world or the map), and the lens, but there will also be as many Frame of References (FoRs)and lenses available in the proximity as there are users simultaneously using the system.

The results of the study lend evidence for the claim that, despite their small physical size and being regarded as personal devices, mobile phones are preferred and voluntarily adopted as means for collaborative efforts in small groups. What we found is that having multiple FoRs is not necessary, but having multiple lenses can be useful. While utilisation of multiple lenses is not linear with the number of users (*i. e.*, not all users use their phones equally all the time), the quantity and quality of collaboration is changed in a number of ways. It is therefore worthwhile to leverage the ubiquity of phones for more collaborative interaction design.

Our studies also suggests a number of further questions to be examined. One such question concerns the relationship of using multiple devices with the size and structure of the shared space. Another important question that was not considered in this study is how showing different, personalised augmentation content on the individual phones – called *subjective views* in literature – affects the simultaneous use. This is particularly interesting if users are able to create or manipulate virtual content in the environment, which was not part of the experience in our study except for photo taking. The very positive results of spontaneous, voluntary, expanded and lightweight place-making and intense collaboration suggest that there should be more interaction design that evoke these properties, with or possibly without AR interfaces.

Specification

Hardware and OS	Nokia N95, Symbian OS v 9, S60 UI 3rd Edition
Software	C++
Core Features	Grabs mobile phone camera image, extracts features from the image, showing a map. Defines the area of the map visible on screen, gets location based media from remote database and displays media, icons on top of map. Enables also content production by uploading geotagged images to Imagination's CityTales2 server.
Status	Second prototype finished in June 2009.
Intended users	Users interested in location based media, events.
Showcases	WP7, others.
Relevance beyond project	Would be usable and extensible over many usage scenarios.

5.3.5 Publications

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Regenbrecht, H. and Juustila, A. (2009). *Like bees around the hive: a comparative study of a mobile augmented reality map*. In Proceedings of the 27th international Conference on Human Factors in Computing Systems (CHI '09) pp. 1889–1898.

Morrison, A., Lemmela, S., Oulasvirta, Schmalstieg, D., Peltonen, P., Mulloni, A., Regenbrecht, H., Jacucci, G. and Juustila, A. (2009b). *From Single to Multi-Lens Collaborative Augmented Reality on Mobile Phones*. Submitted to CHI2010.

Wagner D., Reitmayr G., Mulloni A., Drummond T. and Schmalstieg D. (2009). "Real Time Detection and Tracking for Augmented Reality on Mobile Phones," IEEE Transactions on Visualization and Computer Graphics, 18 Aug. 2009. IEEE computer Society Digital Library.

Wagner, D., Schmalstieg, D. and Bischof, H. (2009b). Multiple target detection and tracking with guaranteed framerates on mobile phones. To appear: ISMAR 2009.

5.4 UrbanSketcher

The User Interface was redesigned for rapid and intuitive Urban Sketching. The main new development is a 2D screen overlay offering commonly used functionality for the user (see Figure 22). The selected command set is meant for fast content creation and manipulation allowing to easily choose from the existing tool set which is a sub set of all the available ones. The large buttons are designed to be used with laser pointer interaction near and at distance from the projection screen enabling a large interaction space which is common in group discussions in front of the screen.

Figure 22 - 2D Menu overlay for tool selection

The 2D menu is activated by moving the mouse pointer into the top left corner of the screen. As the pointer is moved over the first column of the menu the corresponding row of tools is displayed for selection. Once a tool has been selected the menu disappears revealing the MR-Scene for interaction with the chosen tool or a dialogue asking for more specific input is displayed.

5.5 Mobile Media Collector

Architects and designers work frequently in the field. Fieldwork may be related to starting a new design; revisiting the site the design is related to, for additional visions or comprehension of the context of the design. Also, during the construction (in architectural design) the site is often visited to check upon the implementation of the design. Especially with participatory design the participants of design are often met at the site. During the site visitation, especially in the beginning of the design process, the designer aims to grasp the surroundings, context for the design as effectively as possible. The designer may not have the possibility for frequent visits due to costs, long distances and the time required to invest in the visits.

The Mobile Media Collector (MMC) is a mobile device and a set of accompanying application(s) for supporting collecting, browsing, and saving location specific and directional media (using a digital compass) related to a urban design site. The tool concept is designed to enable the designer to:

- **Grasp the site** before the site visit, using zoomable maps and aerial imagery.
- **Planning a visit** to the site, by marking interesting places to visit or paths to drive/walk during the visit.
- Make **location specific notes** of the site using the map, including symbolic, textual, voice recordings, photographs or even small videos.
- **Collecting location specific media** (using GPS location, compass direction) and paths from the site.
- Creation of **2.5 dimensional views** of the visits, where the collected media is presented over a two dimensional map, in their correct location and compass

direction in third dimension. Also, **panoramas** can be stitched from the images with GPS and compass direction data on a server side.

- **Create sketches**, both **on top of maps and photographs** taken from the site, enabling the user to create perspective drawings on top of photographs. Sketches are also zoomed as the maps are zoomed, and vice versa.

The MMC could also include some support for collaborative and presence features:

- In **collaborative** settings, the designer is also able to see other designers' notes, photographs, sketches, placemarks and paths, including the real time location of the user, enhancing the presence aspects in design.
- **Share** design related media and sketches with other designers both while on the site and in the studio or while preparing for a presentation to the stakeholders of the design.
- **Present** the initial design ideas to other participants in the design process, using the sketches on maps and photographs and the location specific placemarks, paths. The presentation is directed from the mobile device and viewed using either a projector or a large display.
- **Plan further visits** to the site, by providing placemarks, paths, media and sketches which can be used to pinpoint the areas that need more attention or are otherwise interesting for the designer.
- **Use the content** created with the tool in other tools and work settings as the content is stored to a HyperMedia Database (HMDB).

The MMC would have to be usable also in settings where a fast network connection is not available. Often, in field trips, outside city centers and main transportation links, there is no UMTS/WiFi coverage. Large maps do not load effectively over GPRS data networks. For this reason, the MMC will use preloaded map files on the device.

5.5.1 Redesign issues

MMC has gone through two prototype development cycles during last two project years. Mobile phones with the Symbian OS and S60 user interface was selected as the platform. Reasons being the availability of 3G and WLAN connectivity on the devices, as well as having devices with integrated GPS and cameras. These features allow the collection of media (sound, photographs, video), geotagging the media and eventually uploading the media to the HMDB.

Feature wise, the first prototype included the following features:

- Recording geotagged voice notes.
- Taking geotagged photographs.
- Uploading the recorded media to the HMDB using Atom Publishing Protocol and HTTP.
- Viewing the geolocated media stored in the HMDB, on Google Maps and Google Earth using the HMDB KML export feature.

The first protype was user tested with students of architecture and land use planning during Fall 2008. Also a group of school children (10 children) from Sevettijärvi village near the Finnish-Norwegian border in the Finnish Lapland used the prototype for three weeks. The architect students were observed and informal interviews in the field were conducted to evaluate the concept and the usability of the first prototype. The stories told by the school children were available for the architects and land use planners in connection with a course focusing on participatory land use planning. There was also a group discussion afterwards with the school children where the prototype usage was discussed and evaluated.

The second prototype added new features and changed the existing ones:

- A story has not only a photo or a sound recording, but optionally both.
- User can optionally enter the compass direction where the storyteller is looking when telling the story.
- User can tag the story as neutral, positive or negative
- User can enter keywords for the story, to aid in searching and browsing the media later.
- User can enter text to describe the story in addition to or to replace recording of the story.
- Downloading a KML (a markup language based on XML for handling location specific data) with placemark data and media files linked from the KML on the device.
- Show the placemark data from KML file and media files on a zoomable Radar view (image below).

Figure 23 - The Radar view of MMC (Kerro Tarina; Tell-a-Story), showing sound files (circles) and photographs (rectangles) downloaded from HMDB.

The second prototype was again user tested with architects and land use planning students, this time in the Ylikiiminki area near the city of Oulu during Fall 2009. The architects were using the tool for augmenting field trips; to collect media and metadata of a place for using it later in the early phase of the land use planning process.

Current devices used in the testing and trials are the Nokia N95 8GB mobile phones. As new touch screen S60 devices are coming to the market, these are considered since the touch interface would be quicker and easier to use in the field (if properly designed), and the screen size allows for larger space for showing content as well as more room for interaction – in the field, while walking, having large enough interaction widgets is beneficial. Also electronic compass support in newer devices support the automatic recording of the compass direction where the user is looking at while telling the story.

The following features were included in the original concept implementation plan, but were not taken forward because of lack of interest and development resources:

- Support for simple maps in the radar view, using open source map databases;

- Support for collaborative features, e.g. seeing where others are now on the Radar view.
- Recording and displaying paths of the users, as well as planning the path for the visit in advance

5.5.2 Related Work

The eDiary in Atelier IST project collects a media path with location data. MMC is not only a data collection tool but also a tool for the initial phases of the design, supporting more complex gathering of design related media and also active sketching [Iacucci2004].

Furthermore, three interaction tools from IPCity bear similar purposes being still from usage and implementation point of view, different. Urban sketcher supports sketching overlays in studio, using 3D technologies. The tool is focused on mixed reality sketching in stationery, not mobile, in the field settings. Scouting concept strives to support real time scouting supporting work in the Tent by streaming voice and/or video from immediate surroundings. MMC is, in comparison, more an independent tool for the designer in the field, even though it also has some collaborative features. MMC would not include real time streaming of video or sound from the site to the studio. AuthOr supports location specific placemarks and paths. This tool is not so much oriented to support collecting location specific, directional (compass) media and sketching directly. Especially with AuthOr, there is a good possibility to reuse code, if similar implementation techniques are selected for MMC. Regarding MapLens, there is the possibility for code reuse, and the GPS as well as HMDB uploading features are now being taken from MMC to MapLens.

Castleden et al. (2008) describe how PhotoVoice method is used to support community participation with indigenous communities (the “First Nation”). They point out the limitation of PhotoVoice that it does pose challenges to photographing non-tangible items or issues. The question of the “owner” of the photographs was discussed, since sometimes they could not associate the person who took the photograph to the actual photograph. Method also includes interviews after a photography session to contextualize the photographs. In our approach, the context (“who, where and when”) is saved together with the photographs as meta-information. As the story (the “why”) is primarily the source of contextual knowledge, which is “only” illustrated by photograph(s), we believe that this augmented storytelling approach is a promising step forward from the PhotoVoice method.

HyConExplorer (Bouvin et al. 2005) focuses on contextualizing of information to support learning outside classrooms. They aim at utilizing the context – time, place and purpose when investigating information in the field. Their construction also supports “annotation of the world”; leaving information related to the physical place where it was created. They use the concept “browsing with your feet” to describe how the information related to a place can be glanced at while moving around places. The technological structure of HyConExplorer is similar than in our approach, but the main idea of the setup is to create content and then utilize that in the field for learning purposes. In our approach, the idea is to create new knowledge in the field, and later on use it in the studio. However, the process of local knowledge acquisition in land use planning can be seen as a learning process. As our current prototype also supports the “browsing with your feet”, the planners have a similar possibility to “be educated” and to learn after the citizens living in the area have externalized their local knowledge using our tools. Technologically HyConExplorer seems to be outdated and the development has not continued after 2006, based on the information on their web pages (http://www.daimi.au.dk/~fah/hycon/html/).

Iacucci, G., Kela, J. Pehkonen, P. *Computational support to record and re-experience visits*. Personal and Ubiquitous Computing. Springer London. ISSN 1617-4909. Volume 8, Number 2 / May, 2004, pp. 100-109, 2004.

Bouvin, N.; Brodersen, C., Hansen, F., Iversen, O.; Nørregaard. *Tools of Contextualization: Extending the Classroom to the Field.* IDC 2005, Boulder, Colorado, USA. 2005.

Castleden, Heather; Garvin, Theresa; Huu-ay-aht First Nation. *Modifying Photovoice for community-based participatory Indigenous research.* Social Science and Medicine, 66(6), March 2008, pp.1393-1405.

5.5.3 Testing and public demonstration

The first prototype of MMC was tested with a group of students of architecture and applied geography and regional planning during September 2008 in a small-scale field test. The students had two Nokia N95 phones with the MMC installed. The tool was used to collect location based photos and stories. No formal study was planned nor executed, but the users were observed and discussed with to get initial impressions on the functionality and usability of the MMC. Some users took mainly photographs, as some were enthusiastic storytellers and liked the voice-recording feature of the tool over the photographic feature.

The main goal of the first prototype trials was that the MMC was given to be used by ten school children in the Sevettijärvi village in the Finnish Lapland near the Norwegian border. The trial was part of a course led by the Department of Architecture at the University of Oulu. This municipal planning course spans four months, during which the students of architecture and applied geography and regional planning visit a municipality somewhere in Northern Finland 3-5 times, during which they make several plans spanning 10-20 years to the future, focusing on the longer term land use planning in the area. The course focuses especially on participatory design and planning. In this case the participation methods included

- a walking tour guided by the local people during the first visit to the municipality of Sevettijärvi;
- a steering group of local people, helping the student to revise their plans during the course;
- a web based tool (Nuojua 2008) for commenting both the local peoples' living environment as well as the plans prepared by the students, and finally,
- the MMC, which was used by the local children to give their views of their own living environment to the students.

The usage of MMC spanned from September 2008 to early November 2008, during which the children rotated the two phones amongst each other. Together they collected nearly 90 stories and photographs. Two students of architecture instructed and also trained the children to use the MMC to especially collect always both a story and a photograph from the same spot. These media files could then be accessed by the architects and planners using the KML export feature of the HMDB, using Google Earth and Google Maps as the user interface.

Figure 24 - A geography & regional planning student using the MMC on the field.

Nuojua, Johanna; Juustila, Antti; Räisänen, Toni; Kuutti, Kari; Soudunsaari, Leena. Exploring *Web-based Participation Methods for Urban Planning*. Proceedings of the 10th Anniversary Conference on Participatory Design 2008: Experiences and Challenges, Bloomington, Indiana, USA, October 1 - 4, 2008.

The second prototype was user tested again during Fall 2009 with another group of architect and land use planning students in the area of Ylikiiminki near the city of Oulu. Twelve students had five N95 8GB phones in use, as they collected stories in the Ylikiiminki area. The stories were used as supportive material to get a “feeling” of the place as the initial planning phase of the area was started. This time, in addition to Google Maps and Google Earth, a special Java based software named MediaBrowser was used to browse and search for the media based on maps, media timeline and author of the media.

In addition to using the prototype in the first field trips, it was also used as a scouting tool. While the planners were working at the studio, one scout with a car and the prototype was available in the Ylikiiminki area. As the planners found that they needed additional images or characterizations of a place, they could advice the scout to the place and then ask for a specific view photographed and sent over to the HMDB. The story was then viewable in the studio, using either the Google Maps/Earth or the MediaBrowser. Some places were indicated already before the scouting commenced as interesting. The scout visited these places, and additional two phone calls directed the scout to other places during the scouting.

The second user test was extensively videotaped by a group of observers who also made notes of the interesting observations to aid later video analysis. Also the situations where the content created using the MMC in the studio was utilized (with Google tools and the Media Browser) were videotaped.

An additional test was conducted with the MMC, more like an ad hoc usability and concept testing case. An actual project aiming to develop two areas in the city of Oulu is ongoing. Here, connected to a seminar related to this development project, a walking tour (gåtur) was organized. We tested the MMC with this gåtur as the users were actual professionals and workers in the project to gain additional insight into different type of usage situations and users. This test lasted for three hours.

5.5.4 Evaluation

The data collected from the Sevettijärvi experiment has been published in Halttunen, Juustila, Nuojua (2009). The usage of the tool was easy and simple. The school children had no problems in using the too. Not so optimal GMS network data connections in Sevettijärvi were problematic, but this was solved by using a WLAN access point installed at the school to upload the stories to the HMDB situated in Oulu. Children collected ca. 90 stories during the three weeks of use. Many of them did not have direct connection with the planning aims of the project though. Students of architecture and land use planners saw the tool easy to use and had several new usage contexts invented for the tool, including building maintenance and using the tool as a location based multimedia note taking tool, replacing or augmenting pen and paper in the field.

The data collected from the Ylikiiminki case has not yet been analyzed, since the field tests have just ended in the end of November. The usage of the tool was videotaped for later analysis, a questionnaire was also filled by the users. Also a group discussion was conducted, based on preselected video clips to aid in highlighting the usage of the prototype in the field.

There were initial plans in using the MMC in the WP9 field tests, but due to changes in organization, planning and resources within the workpackages, this never materialized.

Based on the tests, several new potential features have been indentified and could be further experimented in future projects.

5.5.5 Publications

Halttunen, V., Juustila, A. and Nuojua, J. (2009). Technologies to support communication between citizens and designers in participatory urban planning process. Communicating (by) Design. International conference on research and practice in architecture and Design. 15th-17th April 2009, Brussels, Belgium.

5.5.6 Specification

Hardware and OS	Mobile phones (Symbian OS)
Software	C++
Core Features	Enables the user to collect and view location specific media, also from other users. Assists in taking grasp an area, supporting designers and architects in the initial design phase. Contains collaborative and sketching features.
Status	Two cycles of prototypes with selected features implemented and trialled in user tests.
Intended users	Designers, architects. With modification also other users interested in collecting/creating media in the field.
Showcases	WP6, WP9 (for collecting "city tales")
Relevance beyond project	Would be usable and extensible over many usage scenarios.

5.6 Multi-Touch Display

Last year the Multi-Touch Display was redesigned for the new brief in WP7, environmental awareness. At the end of the year the display was presented at the European City of Sciences (ECS) exhibition, where we also collected an extensive set of data how the display was used and how its new design worked in practice.

During the fourth year, the data collected at the ECS (video footage from two cameras and collection of presence, IMI and flow questionnaires) was analysed. Based on this analysis and additional expert evaluation, we have improved the new user interface paradigm we created that uses 3D widgets.

On the fourth year we focused mostly on interaction analysis and design, the core technology behind the Multi-Touch Display staying the same: 1) multiple hand tracking capable of identifying uniquely as many fingers and hands as can fit onto the screen; 2) hand posture and gesture tracking; 3) high-resolution and high-frequency camera processing up to 60 FPS, and 4) computer vision-based tracking that works in changing light conditions. The technical framework is described in more detail next.

5.6.1 Implementation

The Multi-Touch Display consists of the application called *Worlds of Information,* which is a mashup of the services provided by the multitouch framework. It consists of six interoperating sub-applications/applets, which provide different views to the application content model. The applets are visualized as 3D spheres, or as a transparent front plane, and they are interactive by themselves (i.e., it is possible to spin, resize or move a container sphere, and perform sideways scrolling operations for the front plane). It is also possible to interact with the individual items of the views, e.g., by activation, resizing and rotating actions. Furthermore, content items can be copied from one applet to another by drag-and-drop operations, e.g., by grabbing an active video frame from a media sphere and then throwing it to the front plane.

Software

Cw3D software is distributed into three components. The PC runs the main application and the multitouch framework on top of Windows XP operating system, the content server runs on a Linux laptop, and the SMS server on a Symbian-based smartphone. The software in the main PC communicates with the other subcomponents via LAN, using remote SQL database and RESTful HTTP requests.

Figure 32 shows the software architecture of the system in more detail. The computer vision (CV) module analyzes the camera streams in order to find regions of a certain size and brightness, treats the matching regions as fingertips touching the surface, and associates each matching blob with position, ID and timestamp. CV module then packs all blobs found within a single camera frame into a message that is sent to the multitouch framework for further processing. The sampling rate of the low level input data is thus equal to the camera streaming rate, i.e., 60 Hz.

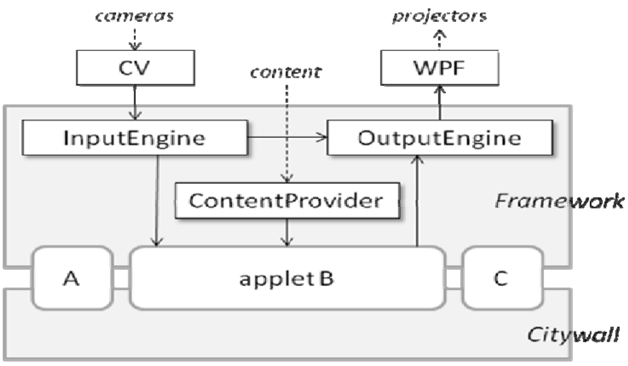


Figure 25. Multi-Touch Display software architecture

The multitouch framework takes the extracted finger objects as the lexemes of the input language. The *InputEngine* component stores the lexemes into a ring buffer, informs the graphics engine about the updated positions, and performs low level time-based analysis in order to find the tokens of the input language. The tokens (i.e., finger down/move/up) are then matched against the positions of the visual elements of the output language, and examined on the widget level in order to extract higher level input features such as dragging, zooming, spinning, throwing and opening actions.

The output language is generated by the *OutputEngine* component, using 2D and 3D visual elements (such as frames and spheres), their child controls (such as iPhone-like scrolling lists), and animation classes (e.g., physics-influenced decelerated rotations). Based on the notifications and analysis results of the *InputEngine*, the *OutputEngine* component is able to give feedback at the lexical level (white circles representing touch points), syntax level (radial progress indicator used with press tokens), and at the semantic level (moving, zooming and spinning actions). There is very little feedback at the syntax level, indicating directness of the interface.

The mapping between input and output languages are handled using interactive visual 2D/3D objects called widgets. Each widget has its appearance (the look) and gesture mapping strategies and transformation properties (the feel). Thus, the widgets are the equivalents of controls in traditional WIMP interfaces. Examples of 3D widgets include picture and video frames, container spheres coated with picture planes, and 3D navigator crossmenus. The widgets may create hierarchies both in container-child and behavior-inheritance dimensions.

The third component of the framework provides the model and content support for the applications. It defines a unified container and media item interface, so that the application does not need to be concerned whether the items are coming from external databases, RSS feeds or web services. The pictures and videos are downloaded by a script running in the laptop computer, which is also hosting an external database with the metadata of the downloaded items. The SMS messages are collected from the mobile phone running on top of a PAMP stack, using the phone embedded HTTP server and RESTful PHP-scripted frontend outputting RSS-format feeds of the inbox contents. Finally, comments associated with the downloaded pictures are updated in realtime using the web service interface from Flickr.

The CV module is based on the earlier Cw version, was ported to Windows and wrapped inside a managed code interface using C++. The framework and the main application run on top of .Net 3.5 and Windows Presentation Foundation (WPF) frameworks, and were written using a combination of object oriented and declarative languages (C# and XAML).

Hardware

The system hardware comprises two video cameras, two projectors, two infrared light sources, a pair of speakers, a mobile phone, a content server laptop, and a PC (see Figure 33). A glass surface, covered from the inside with white diffuser material, serves simultaneously as an interactive multitouch surface and a back projection display. As the users are interacting with the system by touching the glass surface, the infrared light emitted by the IR sources is reflected back from the touch points, and captured by the video cameras. For visual output, the displayed graphics are in turn reflected via a back panel mirror in order to increase the effective distance between the projectors and the display surface. The system contains also a stereophonic audio output channel and a mobile phone to receive SMS text messages from the users.

The cameras, projectors, speakers and the IR source controller are connected to the PC via PCI- or motherboard ports. Although the projectors can be interfaced using a single dualhead graphics card, the Firewire cameras demand separate interfaces to reach the required 60 fps streaming rate. The PC, content server laptop and mobile phone are connected into a LAN via a router device, which enables also an access to the internet.

The portable version of the Multi-Touch Display houses all equipment in a 2 meter X 2 meter X 1.5 meter sized kiosk, which can be assembled at the installation location. In addition to hiding the implementation details and providing the framing for the surface and the mirror, the kiosk sports also an overhead lid to protect the visual tracking mechanism from disturbing environmental reflections.

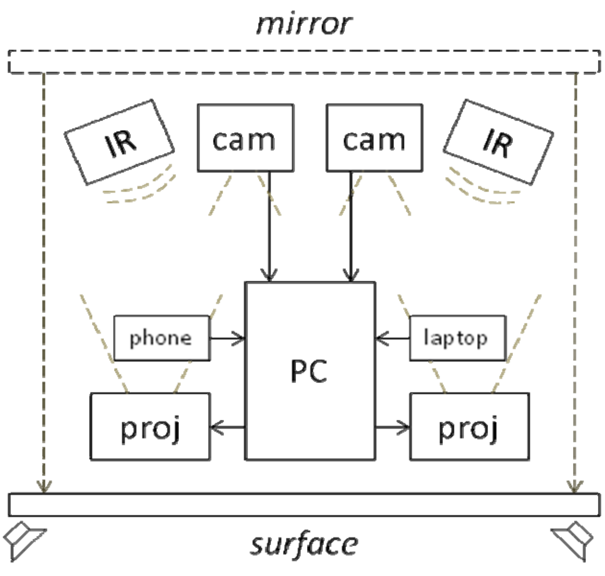


Figure 26. Citywall hardware. A dual camera/projector setup is required to cover the entire interaction surface.

5.6.2 The 3D interface paradigm

Challenges and Design Goals

In our previous evaluation of Multi-Touch Display (see D7.2 and Peltonen et al. 2008) we detailed the social usage of an interactive public installation. We described how passers by approach and form crowds, engage in parallel and collaborative interaction, social learning, conflict management, negotiations of transitions and handovers, playful, and performative interaction. We resolved that the interaction could be improved as the use was characterized by being ephemeral, driven by the playfulness of the interface, and permeated by unnecessary conflicts. We aimed at improving upon the existing two-dimensional version of Multi-Touch Display, with its singular timeline and therefore no possibility for multiple content categories. In particular, we wanted to keep the possibility for several people to interact simultaneously at the display as a central aspect of fostering engagement through socially experiencing and learning the installation.

Multiplicity of Content. According to our experience with passersby, local institutions and stakeholders, it is important to allow for a variety of content themes or categories. The aim is to be able to attract passing public with multiple relevant topics to foster and support conversations.

Multiplicity of Users. In our earlier 2D interface implementation, we treated the entire display as a single interaction space, meaning that one user's actions often had effects on the actions of another user. For example, resizing an image to a very large size might overlap another user's focus of interaction, and moving the single timeline means disruptions for others because all the photos in the content then start moving left or right accordingly. Our goal was to allow individuals and groups to be engaged in different types of processes at the same time (or to work together using the same processes).

Gradual Discovery. The aim in designing CityWall was to have an intuitive interface where novice users could easily approach and easily use the interaction techniques. Such a "Walk-up-and-use" system needs to be so self-explanatory that first-time or one-time users need no prior introduction or training. We saw that by implementing our design changes we could disrupt this ease of use, and while we also aimed to extend the scope of the interactions beyond this early learning curve, we looked for a balance. We wished to retain ease of first use, and structure complexity in a scaffolded way, unpacking the functionality and content gradually as one means of enabling sustained interaction.

Design Solution

Worlds of Information

Working towards these design goals, we sought to develop an interface that would allow us to present large amounts of multi-themed content - originating from multiplicity of content sources - in a way that also affords parallel interaction. We found that using multiple virtual 3D container objects (spheres or widgets), sitting on the display side by side, would offer a feasible solution. Each virtual 3D sphere could provide an individual interaction access point, with an independent timeline, and a collection of these 3D spheres would then enable parallel interaction within a shared display space (see Figure 35).

Figure 27. Different worlds with different themes can fit side by side on the display screen. The worlds are shown here in their collapsed state, hinting the themes with distinct wrapping textures, while hiding the actual contents.

As the overlying theme of the work was environmental awareness, worlds proved appropriate conceptual and functional 3D metaphors for the containers, and were shapes that could readily expand to add more layers of information. The envisaged two-meter screen could easily accommodate multiple spinning spheres, or as we now came to think of them, *worlds of information*, each with its own theme (see Figure 34). We used six individual globes that contained themed information, in the form of images, videos and text. These worlds housed images of Helsinki since 2007; images of the venue of the installation; videos of state of the art multitouch systems; SMS, MMS, and email messages sent to the system; help animations; and images from participants of a nearby installation.

Opening and Navigating a World

Stretching the sphere over a certain threshold size opens the world, while resizing to the opposite direction will shrink the world back to the collapsed state (see Figure 35A). In the opened state, the container sphere is coated with 2D plates, each holding an information item belonging to the themed timeline. An opened world can be further enlarged, moved along and spun around the x- and y-axis, in order to browse the photo, video and text items attached to the sphere.

Figure 28. A. Closed world. B. World opening, animated using fade ins and radial beams. C. Opened world.

Spinning the world rapidly around its y-axis (i.e., to the left or right) allows navigating back and forth through time to view older and newer content according to the theme of the world: the current layer of coated items is replaced with another layer of items from preceding or succeeding dates. To this end, the sphere consists of multiple stacked layers of content, which can be exposed by peeling or spinning actions (see Figure 38A). It is also possible to jump directly to a specific date by activating the navigator menu (see Figure 38B). The menu items in the equatorial circle represent days of a month, while the items in the longitudinal circle denote months and years. Both circles can be spun around to make a selection of the date that is presented with the larger frontal item.

Figure 29. A. Navigating backwards in time, current layer is exploded out while a new layer is faded in. B. Navigator menu, date label at the bottom of the sphere.

Pieces of Information

The pieces of information contain images, videos and text items that are tagged with a title, author and timestamp metadata. They are visualized using 2D plates that are inclined in 3D to cover the spherical surface of a world. A single content item can be selected for closer inspection: this action rotates the world to an angle which brings the item to the front of the sphere, where it appears larger that the other items (see Figure 38A). This close-up position allows them to be resized and flipped around to read the associated comments (Figure 38B). It is also possible to make copies of the close-up item, and add these to the communal 2D front plane of the interface. To support co-operative interaction tasks further, we overlaid the entire display space with a virtual transparent interaction area (see Figure 37).

Figure 30. 2D front plane and 3D worlds co-exist.

In addition to the copied content, the front plane holds recent text messages, which can be moved, resized, rotated, played and dismissed by any user. This horizontally scrollable layer corresponds to the 2D content area of our earlier implementation. Consequently, the ability to enlarge the items and the worlds, and to overtake the whole display area, ensured we maintained the accidental parallel and associative interactions that had enabled sociability between relative strangers at our previous implementation.

Figure 31. A. Content selected and enlarged. B. Flipped around to read associated comments

Help System

The help topics are presented as spheres that are in constant motion. The main help world travels slowly around the interactive space, emitting slogans that encourage people to try the interface (occurring only in periods of inactivity at the interface). The system also contains small help spheres travelling at a faster speed. The idea is that people become engaged in catching these help spheres, and once caught, the sphere opens up and show its contents (main help), or play a short animation (topic) that explain the gestural language of the interface (figure 6).

Figure 6. Examples of opening, closing and spinning gestures

Gesture Language

The challenge of the gestural language design was that the virtual objects in the 3D space require six degrees of freedom (DOFs) to be manipulated in full detail (i.e., translations and rotations in all three dimensions). In contrast, the multi-touch input is sampled from a 2D surface, giving only 3 DOFs (translation in the x/y dimensions and rotation around the z-axis). Looking at the functionality of the system introduced in the previous sections, we can summarise the operations as shown in the first column of Table 2. Gesture mapping. Column 'item (3D)' lists gesture mappings of a content item attached to a world, while column 'item (2D)' lists mappings of a front plane item.. These operations needed then to be mapped to the available multi-touch gestures.

Table 2. Gesture mapping. Column 'item (3D)' lists gesture mappings of a content item attached to a world, while column 'item (2D)' lists mappings of a front plane item.

operation	world (3D)	item (3D)	item (2D)
open/close	stretch	press	stretch
spin	drag		
move	drag	*(x)*	drag
resize	stretch	stretch	stretch
rotate	*(x)*	*(x)*	circle
throw	flick		flick
flip		flick	
copy	*(x)*	drag	*(x)*
play/stop			press

We decided to extend the gesture language of our previous 2D implementation to work with the added dimension. The original language alphabet comprised four gestures: 1) drag – moving fingers on the surface, 2) stretch – two or more fingers moving in opposite directions or towards each other, 3) circle – two or more fingers moving in a circular fashion, and 4) flick – a rapid dragging action. We introduced only one additional input language component – press – generated by touching the surface and holding the finger down for 2 seconds.The mappings are presented in the three rightmost columns of Table 2.

Some gestures needed to be overridden because of the differences in the amounts of input and output DOFs. The first conflict arose between the spinning and moving operations associated with the 3D spheres: the dragging gesture extends naturally from moving in 2D to spinning in 3D, but in doing this, the move operation gets masked out. To distinguish these operations we had to count the number of touch points on the sphere: 3 fingers or less triggered spinning, and 4 fingers or more triggered the movement operation. Table 1 contains also several cells marked with *(x)*. These mappings were not included in the language, because we noted that it became increasingly difficult to control the 3D model when the number of DOFs was increasing. The empty cells denote operations that do not make sense in the corresponding context. Finally, we also experimented in using double tap gestures in place of press gestures. We had to choose the latter because external disturbances resulted in falsely triggered taps.

References

Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., Oulasvirta, A., and Saarikko, P. (2008). "It's mine, don't touch": Interactions at a large multitouch display in a city Center. In Proc. of the SIGCHI conference on human factors in computing systems (CHI'08), ACM Press, New York, pp. 1285-1294.

5.6.3 Testing and public demonstration

The technology is used in the environmental awareness showcase WP7. The Multi-Touch Display techonology is used as the basis of the permanent CityWall installation in Helsinki city centre where anyone can go and try it out.

5.6.4 Evaluation

An extensive analysis of the data gathered at during the ECS exhibition was conducted in 2009. Both video data and surveys were collected as part of the field evaluation. The video data provided observations of participants in-situ across three days of the exhibition. The researchers worked with a visiting researcher to complete the video analysis in an effort to reduce bias. The surveys were not compulsory and a convenience sample of 101 users completed them. We present the video analysis evaluation results here and the questionnaire (which we used to evaluate presence, motivation and flow) in D7.4.

For each of the three days of the exhibition several hours of video were recorded. All the three days of video data was analysed using the third day of the exhibit as a purposive sample for more in-depth analysis. In addition, two hours of continuous video footage was analysed using Erickson's (1992) method of "microanalysis." This technique is particularly useful when trying to understand the common and distinct elements of events that occur. The video data was examined to understand how individuals, groups and pairs configured themselves around the system; what system states occurred as a result of the interaction; how users worked together or separately; what sort of interaction techniques users employed; how users learned how to use the system; and how the interaction sessions were structured.

For the participants we video taped and observed using the system, the ages ranged from infants (with families) to people in their 80s. An exact number of participants and their demographic information was not obtained, but the surveys were used to obtain descriptive information of a subset of the sample.

Supporting Multiple Configurations and Parallel Interaction

We observed 20 configurations of use around the system, which are illustrated in detail in Figure 40. While each of these observations were unique instances of use, they often involved the same participants reconfiguring themselves around the system based on changes in the system, or their engagement. Often the configurations would perform like a dance, with users working alone, then collaborating and then working alone again, or vice versa. A configuration was labelled as individual if one person engaged in focused manipulation of one object or area of the screen without interacting with or avoiding interaction with other users. It was labelled as pair if 2 users began to manipulate an object or objects together or talk and interact with each other while manipulating objects. It was labelled as group if 3 or more users engaged in the same manner as a pair. Results are depicted in Figure 39.

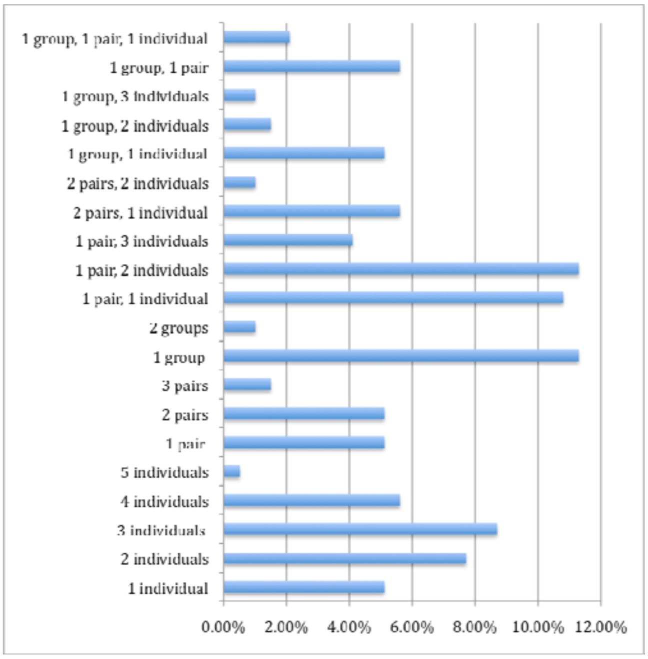


Figure 32. User Configurations around the Wall, with a total of 195 occurrences. 8

We also analysed the overall individual use, pair wise use and group use, finding that the most frequent use was individual (47%), followed by pair wise (35%) and group (18%). Figure 41 shows the distribution of occurrences for different configurations. We can analyse the support for multiple use by grouping the above as interaction spots. Following this we group as 1 interaction spot occurrences of 1 pair, 1 individual and 1 group, 2 interaction spots combinations or two of the latter, and so on. As can be seen from the Figure 39 and Figure 40 interaction spots account for most occurrences with 4 and more still having a sizeable portion.

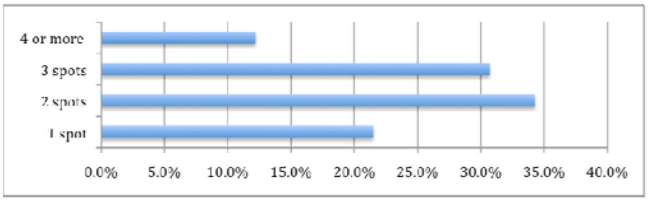


Figure 33. Configurations into number of interaction spots. 9

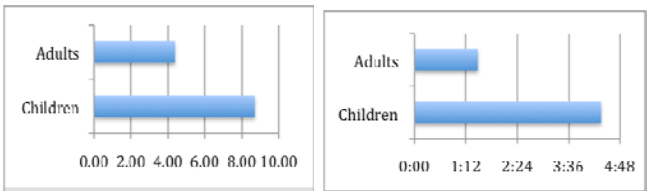


Figure 34. Average number of configurations and length of time of use by an individual at the wall. 10

Coupled with understanding of the most common configurations of users around the system and how the users would configure themselves, we also were interested in understanding the average length of time that a user would interact with the wall and the average number of configurations they would take on. Analysis revealed that, on average, an individual would stay at the wall for 2 minutes and 33 seconds, and be part of 6 configurations.

However, analysis also revealed that there were distinct differences between adults and children. Once the two groups were analysed separately, we found that children tended to interact with the wall much longer than adults. Children, on average, interacted with the wall for 4 minutes and 21 seconds, while adults stayed for 1 minute and 29 seconds, on average. As a result, children tended to take on 8.7 configurations, while adults took on 4.4. See Figure 41.

Gradual Engagement

We identified five distinct system states that influenced interaction and configuration by users. The states of the system are not linear, and the system can go back and forth (depending on use) through any of the states, with the exception of the first. During state 1, the system is at its initial state with the worlds closed and discrete interaction zones. During state 2, one or more of the worlds are open, but the interaction zones are still discrete. During state 3, the interaction zones are mostly separate but partially overlapping, meaning that one or more worlds or objects partly intersects another initially distinct space. During state 4, at least one world or object is overtaking one-third or one-half of the space but there is still at least one separate interaction zone. During state 5, one or more worlds or objects completely takes over the space.

Everything starts with one finger. Users were most likely to attempt to manipulate objects with one finger initially (see Figure 42), especially when not influenced by other users' of the wall. One-finger interaction was often not a problem for users who would start interaction when trying to manipulate an open world or a picture. During those times, users would often be able to rotate a world or pull out a picture, which was most amenable to one-finger interaction. *Difficulties opening the worlds*. One-finger interaction didn't lend itself well to opening a world. In the cases where someone was successful, it was often by accident (i.e., pressing on the world for a long period of time or moving a finger around the world, hoping to spin it but instead opening it), or by observing someone else.

Figure 35. Left: One-finger interaction; Center: one-handed interaction; Right: two-handed, one-finger interaction. 11

From one finger to two handed interaction. Often, one-finger interaction would become partial or full one-handed interaction or two-handed, one-finger interaction as users would attempt to enlarge or compress pictures or worlds. Often full one-handed interaction or two-handed, one-finger interaction starts accidentally (unless the user had observed someone else successfully using the technique) and becomes a more and more refined intentional manipulation. Intermittently, users would start with one full or partial hand interaction, but this typically happened in cases where they encountered the screen at state 3 or 4 and attempted to move an object or picture already situated on the screen.

Figure 36. Interaction with two full hands was the most effective for enlarging objects, especially the worlds. 12

The use of two full hands for manipulating objects was a less intuitive response by users (unless they had observed someone else using the technique) but it was the most effective for enlarging objects, especially the worlds (see). Users who stayed at the wall longer than average usually ended their session with two full-handed interaction, and influenced other users to do the same. A typical user would not start with two-full-handed interaction unless influenced by another user. One of the cases we observed involved a woman who attempted to open a world in the same way that she enlarged a picture (see Figure 44). She initially started with one finger interaction, flicking pictures around on the screen. Then she decided to open and close her hand on one of the pictures and discovered that it opened in response. She decided to try that interaction technique on a closed world. Unfortunately, she wasn't successful in doing so. As a result, she adjusted to two-handed, one-finger interaction, which resulted in successfully opening the world. A second case studied involved a pair (see Figure 45). Two men were working together, manipulating objects with one full hand and talking. They accidentally started working with the same picture and realized that by having each of their hands on the screen, they were able to make a picture larger. One man learns, as a result, that he could use two full hands to make that same picture smaller.

Figure 37. Case 1: A woman learning two-handed interaction. 13

Figure 38. Case 2: Pair learning two-handed interaction. 14

Social Learning

There were four types of techniques that users employed to understand the system: *individual exploration, cooperative exploration, passive observation then attempt* and *imitation.* Individual exploration is defined as one user testing out techniques with the system independently without observing or working with others. Cooperative exploration defines users who work together in pairs or groups to understand the system. Passive observation and attempt is defined when users watch others using the wall and attempt to imitate their use or try out their own strategies. Imitation is defined when users go directly to the wall (without observing others initially) and imitate how other users work with the wall while they are there. Most users would use a combination of two or more of these techniques when using the wall. The most frequently cited learning techniques were cooperative exploration and passive observation followed by attempt, which often worked in tandem.

Figure 39. Case 3: An example of passive observation followed by attempt and cooperative learning.

Case study 3 (see Figure 46) illustrates how users learned both through passive observation followed by attempt and cooperative learning. A man observes others using the wall but starts his interaction with one finger. A young boy at the wall starts talking with him about the wall and shows him a technique he has used. As a result, he starts to successfully work on his own section of the wall. A woman comes to the wall and starts to work with him. In the process, he learns a new technique (how to turn a picture around to view comments) and shows her what he has learned. Imitation and individual exploration were less frequently cited, probably due to the nature of use at the wall, which was often continuous. Imitation worked successfully when employed in a similar vein to passive observation and attempt because users could learn from others around them. Individual exploration varied in success depending upon the interaction techniques users employed. For example, in the first case study (Figure 45), the user had observed several users successfully opening and closing worlds with two full hands, but she decided to start with one finger interaction. However, having watched others in their attempts may have helped her determine that two-handed, one-finger interaction would later be a better choice for opening the worlds. This may have been an attempt by her to understand if the system would be amenable to another interaction technique.

Conclusions and Implications for Design

We set out to design for engagement for a public multitouch installation. Supporting multiple users and multiple content have been addressed concurrently by providing several separate *worlds*. Gradual discovery of content and functionality, which is particularly challenging in a public display for the short character of sessions, has been addressed first of all by providing opportunity with the separate worlds for parallel interaction. Secondly, the worlds provide a gradual unfolding of the content and functionality.

As the observational data demonstrated, the most frequent configurations of users involved multiple individuals working in groups or pairs, and the instances of individual use that were highest were in tandem with another individual, pair or group configurations. This demonstrates that the system frequently accommodated multiple users, and different coupling styles (Tang et al. 2006). Another finding was that users were influenced by others, both through observation and collaborative exploration, as pairs and groups often influenced each other on the wall. Further, survey data indicated that users felt that they engaged in a shared experience with others, but did not change their actions in response to them, indicating that they could share the space without compromising individual exploration. The 3D Spheres and the metaphor of the worlds proved to be effective solutions to provide mobile territories (Tang et al. 2006) and access and entry points (Hornecker et al. 2007). In particular Worlds, when they are unused invite explicitly passers by to interact, even if someone else is interacting with another world.

Our solution adds a 3rd dimension to a multitouch interfaces that are generally 2D and applies the metaphor of Worlds different from other metaphors used for similar purposes (Forlins and Shen, 2005; Hinrichs et al. 2006; Everitt et al., 2005; Tobiasz et al. 2009). The interface solution we proposed worked but uncovered a variety of problems in particular for a wall and for public display. We manage to identify these design implications: 1) Accompany the users through the exploration of the functionality. This could include having the help balls be brought contextually to the attention of the user in the right moment. 2) *Worlds* could be animated to go back more promptly to the starting collapsed state to be able to offer people exploration from the beginning. Additionally, the starting collapsed state should be made more intuitive to open. 3) Spinning and Timeline navigation should be made more visible and easier to understand, as well as the functionality of uploading and sending content. 4) Controlling size and position of worlds. This could be used to better support stability of some of the configurations of people at the display by limiting the behaviour of the *Worlds*.

References

Erickson, F. The interface between ethnography and microanalysis. (1992). In LeCompte, M.D., Millroy, W.L. and Preissle, J. (Eds.). *The handbook of qualitative research in education*. Academic Press, San Diego, CA, 201–225.

Everitt, K., Shen, C., Ryall, K., and Forlines, C. Modal spaces: spatial multiplexing to mediate direct-touch input on large displays. In CHI 2005 Extended Abstracts, ACM Press (2005), New York, 1359–1362.

Forlines, C. and Shen, C. DTLens: multi-user tabletop spatial data exploration. In Proc. UIST 2005, ACM Press (2008), New York, 119–122.

Hinrichs, U., Carpendale, S., Scott, S.D. and Pattison, E. Interface Currents: Supporting fluent collaboration on tabletop displays. In Proc. SG 2005, Springer (2005), Berlin, 185–197.

Hornecker, E., Marshall, P. and Rogers, Y. From entry to access: how shareability comes about. In Proc. DPPI 2007, ACM Press (2007), New York, 328–342.

Tang, A., Tory, M., Po, B., Neumann, P. and Carpendale, S. 2006. Collaborative coupling over tabletop displays. In Proc. CHI 2006, ACM Press (2006), New York, 1181–1190.

Tobiasz, M., Isenberg, P., Carpendale, and Lark, S. 2009 Coordinating Co-located Collaboration with Information Visualization. In Proc. InfoVis 2009, IEEE.

5.6.5 Development & research

Based on the analysis we did this year, we have improved the Multi-Touch Display in the following ways:

- Date menu enhanced:
  - months that have content are now highlighted with green color so that users know where they should navigate

- bug fix: Also months beyond March/09 can now be shown

- Support for content management system
- Different worlds can now be removed and added via web based content management system (for more details on ContentManager development, see D5.4)
- Soft keyboard and related functions implemented
  - users can now write short text messages that go into PinBall world (see Figure 47).
  - users can now comment existing content and comments go behind the content plate and can be seen by flipping the plate
- Support for more stable MMS messaging via UOulu's MessageBridge (bluetooth connection)
- Image messages and SMSs can now be sent to CityWall's PinBall world by mobile phone.
- Logging system: every user action gets now logged
- Added aural and visual notifications when new content arrives
- Closed PinBall world starts shaking and notification sound gets played when new content arrives via soft keyboard or MMS
- Moving objects (HelpBalls and InfoBall) made easier to catch
- Users don't need anymore to hit exactly the moving objects with a press gesture: moving objects can now be stopped by dragging a finger over them.
- Drawing application: users can now draw simple images that go into PinBall world (see Figure 47).

Figure 40. New Multi-Touch Display features: drawing and keyboard.

- WatchDog application: checks whether the main application is running properly and restarts it if there's a problem (if the main application crashes or freezes due to some unknown error).
- Videos start now playing right away when they are brought into a close-up position (they play on the content tile).
- Collision detection added for non-Wandering applets (for the actual worlds) and worlds can no longer go beyond the screen boundaries.

- Minimum and maximum scaling threshold set for the worlds: worlds can no longer be scaled too small or too large

5.6.6 Specification

Hardware and OS	Data Projector, Camera, Infrared lenses and filters, Infrared emitters, Multiple cameras and projectors are supported to handle larger screen (so far 2 IEEE 1394 cameras with 60fps and VGA resolution have been used with maximum of 4 projectors), PC Hardware, Windows XP
Software	The software consists of two parts: 1) touch-display manager (written in C++) and 2) application layer. (written in C#) A high definition IEEE 1394 (FireWire / i.Link) camera with IR lens is used to track objects near the screen. The computer runs touch-display manager software that • captures images from the camera (platform-specific) • calculates touch-points from the images using computer vision methods (platform independent). Image processing is done in the background at a fixed rate (regardless of the application). The application sees the touch-screen as providing new fully-processed input samples at fixed rate. Support for multiple screens and cameras Separate, dynamic calibration for each camera is implemented (a calibration application for setting up the projection parameters interactively has been developed) and information is merged at the edge of the camera images. Each camera image is processed in a separate thread. Multi-head key-stoning is handled with OpenGL transformation matrix. A separate, stable API layer provides all the important information from the computer vision.
Core Features	Multiple point touch-screen interaction Detecting points of contact, tracking of fingers at 60 FPS Operation in day and night mode Multiple interfaces for the application layer
Status	Prototype
Intended users	Citizens and visitors
Showcases	WP7
Relevance beyond project	This component has raised a lot of interest and has made possible the creation of a startup that commercializes products and services for multi-touch screens (see D7.4).

6 Final Period Dissemination

6.1 Publications

Halttunen, V., Juustila, A. and Nuojua, J. (2009). Technologies to support communication between citizens and designers in participatory urban planning process. Communicating (by) Design. International conference on research and practice in architecture and Design. 15th-17th April 2009, Brussels, Belgium.

Jacucci, G., Peltonen, P., Morrison, A., Salovaara, A.,Kurvinen, E., & Oulasvirta, A. (in press). Ubiquitous media for collocated interaction. In Willis, K. (Ed.), *Shared Encounters*. Springer Series on CSCW.

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Regenbrecht, H. and Juustila, A. (2009). *Like bees around the hive: a comparative study of a mobile augmented reality map*. In Proceedings of the 27th international Conference on Human Factors in Computing Systems (CHI '09) pp. 1889–1898.

Wagner I., Basile M., Ehrenstrasser L., Maquil V., Terrin J., Wagner M. *Supporting the Formation of Cummunities of Practise; Urban Planning in the MR-Tent.* In: C&T 2009.

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Regenbrecht, H. and Juustila, A. (2009). *Like bees around the hive: a comparative study of a mobile augmented reality map*. In Proceedings of the 27th international Conference on Human Factors in Computing Systems (CHI '09) pp. 1889–1898.

Morrison, A., Lemmela, S., Oulasvirta, Schmalstieg, D., Peltonen, P., Mulloni, A., Regenbrecht, H., Jacucci, G. and Juustila, A. (2009b). *From Single to Multi-Lens Collaborative Augmented Reality on Mobile Phones*. Submitted to CHI2010.

Wagner D., Reitmayr G., Mulloni A., Drummond T. and Schmalstieg D. (2009). "Real Time Detection and Tracking for Augmented Reality on Mobile Phones," IEEE Transactions on Visualization and Computer Graphics, 18 Aug. 2009. IEEE computer Society Digital Library.

Wagner, D., Schmalstieg, D. and Bischof, H. (2009b). Multiple target detection and tracking with guaranteed framerates on mobile phones. To appear: ISMAR 2009.

6.2 Other forms of dissemination

Many of the building blocks developed within this workpackage such as the Authoring Tools and Colour Table have been used extensively within dissemination activities such as The FET Conference, Summer School and the Final event. For more inforation on where they have been used please refer to D1.14, D1.15 and D2.9.

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For further information regarding the IPCity project please visit the project web site at:

ipcity.eu