IPCity

Integrated Project on Interaction and Presence in Urban Environments

FP6-2004-IST-4-27571

ipcity.eu

Improved Prototypes of Interaction Tools
Deliverable D4.3

Doc-Id:	D 4.3
Version:	1.0
Author(s):	Thorsten Fröhlich, Antti Juustila, Ann Morrison, Peter Peltonen, Gerhard Reitmayr, Jan Herling, Lisa Ehrenstrasser, Wolfgang Broll
Date:	2009-02-13
Status:	Final
Availability:	Public
Distribution:	Project Partners / EC / Web

Table of Content

Abstract

The cross-reality interaction tools research workpackage 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. No standard interaction techniques have yet been established in the area of mixed realities – unlike the WIMP metaphor on windows desktop systems. This especially applies to mobile mixed reality environments. Additionally, interaction techniques often involve multiple modalities. Beside this, individual platforms require individual solutions, while they should at least partially be exchangeable for the individual user. Support for user interfaces and interactions should however not be limited to system and implementation aspects, but also include appropriate support for authoring, or else creators of mixed reality content will be overwhelmed by the complexity of the process.

In that sense we have continued developing the second year's demonstrator and started a couple of new technologies, e.g. the Multi-Touch Display and the Augmented Map Table. Basis for the work in this year have been the results from the showcase evaluations and review and redesign discussions of the consortium.

This document summarizes the scientific and technical achievements in workpackage 4 during the third year. According to the internal report I4.5 which includes a redesign analysis for all year two demonstrators for WP 4, revised prototypes have been developed which have been tested within several showcases.

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 III	(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 III	• **Interaction Prototyping/Authoring:** A graphical user interface on top of the language describing the interactions will be developed. This will be a major building block together with the language to support easy creation and evaluation of new interaction mechanisms. • **Authoring and Orchestration Interface:** This tool supports the showcases by augmenting arbitrary maps with 2D information, e.g. text, objects, users. The functionality can be used to author a showcase event as well as orchestrating and monitoring the running event and evaluating an event by playback functionality. • **Audio / Video Streaming:** Publishing arbitrary audio and video sources to local and remote hosts in an efficient way, while providing a simple interface in order to access a stream. Integrate the streaming into the device abstraction. • **Augmented Map Table:** Integration with the existing application components Urban Sketcher and Color Table. The map table will present a tangible interface to various elements manipulated in the Urban Sketcher and Color Table, such as drawing planes and placeholder objects. • **Tangible User Interfaces:** Clarifing design issues related to the collaborative creation of mixed-reality configurations and making use of material and spatial properties in designing both, physical interface, as well as multiple and simultaneous interactions. Developing and applying methods allowing users to rapidly learn, use and understand the interactions with the **ColorTable** to gain a basic understanding of the user's presence related to interaction.

	• **MapLens** (augmented maps on mobile devices over paper maps): Development of the mobile client on Symbian OS smartphone in collaboration with HIIT/TUG/CAM. Field trials planned in Fall 2008. • **Mobile Media Collector:** Design and development of the tool for collecting and browsing location based media using mobile devices. First prototype implementation planned in Fall 2008. • **UrbanSketcher Interface Streamlining**: UrbanSketcher will also undergo extensive user interface redesign, e.g. usability improvements, strengthening the collaborative properties, enhanced visual and/or audio feedback of user action, or additional functions to handle the assumed ground plane in the MR scene. Additionally developing of sketching/3d modelling tools. • **Multi-Touch Display:** Set up of an infrared tracking based touch screen with rear projection. Development of a catalogue of gestures to manipulate virtual objects using multiple fingers.
Results Phase III	No new tools have been developed within phase III (1a). The following tools from phase II 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 developed using natural feature tracking as part of collaboration between HIIT / OULU / TUG / CAM. Three field trials were conducted, testing the integrated system. • **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. The implementation has now reached the prototype 1 phase and will continue after the trials of Fall 2008 to prototype 2 phase. • **Multi-Touch Display:** An infrared tracking based touch screen with rear projection has been developed that has also been extended to support 3D object manipulation. A language of natural gestures to

	manipulate virtual objects (both 2D and 3D) using multiple fingers has been created. Display was exhibited at the European City of Sciences in Paris, France and on permanent installation in downtown Helsinki.
	No pre-existing tools have been extended within phase III (1c).
	The following tools have been requested by other projects or third parties (5):
	• 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
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 will be conducted during Spring and Fall of 2009.
	MMS Entrance: Further trials integrated to Multi-Touch Display.
	ColorTable: Further development including all the result from the user workshops and further trials and user workshops.
	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.

2   Review Report Feedback

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

Rather than using the best technology available, we look to a make a rational attempt to define the optimal requirements for all aspects of the project. For MapLens and CityWall, the demonstrators for WP7, the optimal is to ensure the showcases reach the lowest common denominator of technology available to a psssing public. For example, as most people have SMS then we utilise SMS to ensure that all of the passing public can use CityWall. In this way the technology follows what the conceptual development of the project tries to achieve, rather than using the latest technology mindlessly because we can, because it is there etc. In this way for WP7 we also ensure we continue to extend the bi-directional interactive possibilities of the projects, addressing the real audience and stakeholders in the urban environment where CityWall is situated.

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.
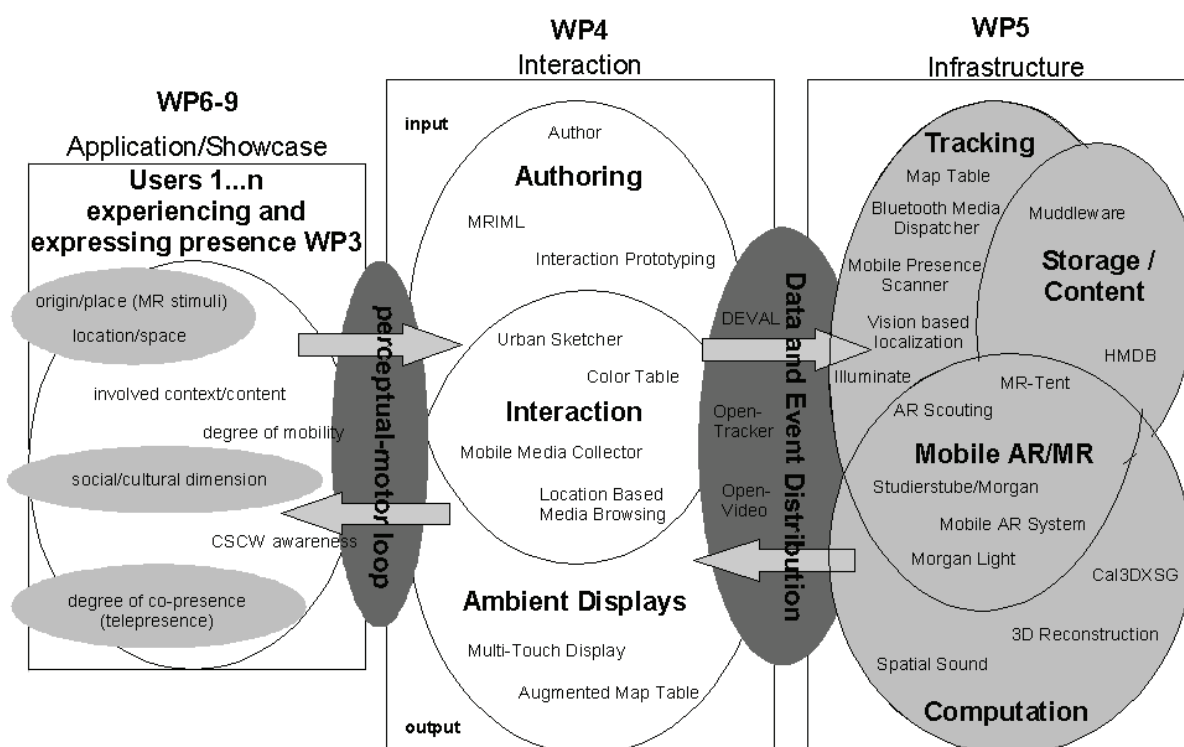
Figure 1: Conceptual Infrastructure Framework Overview

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.
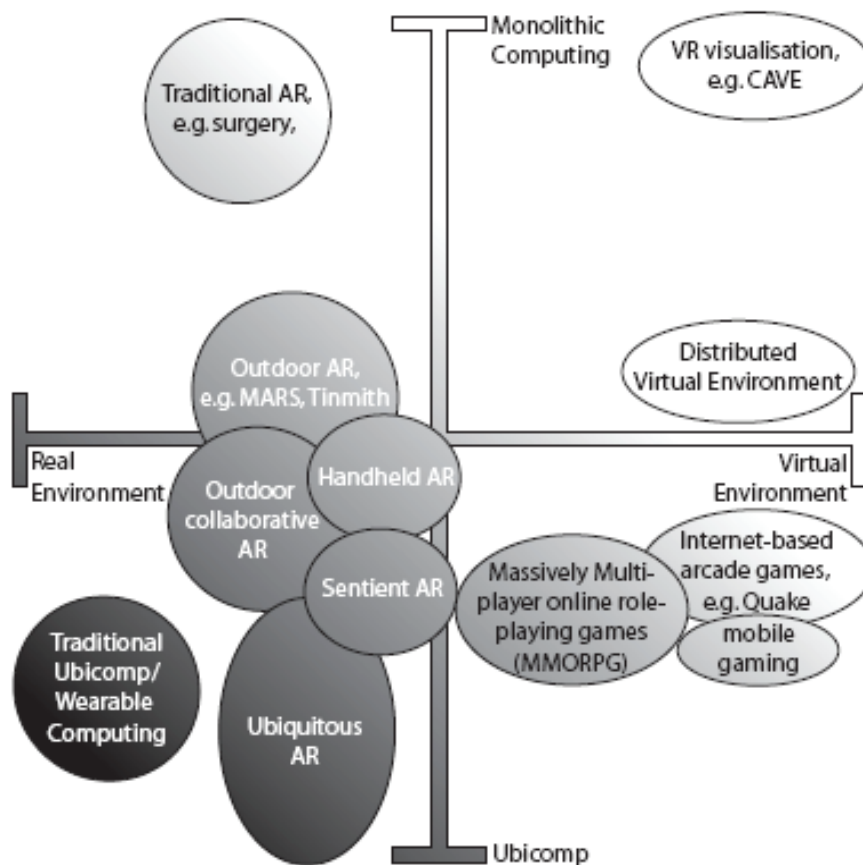
Figure 2 - Milgram-Weiser-Newman Continuum

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.
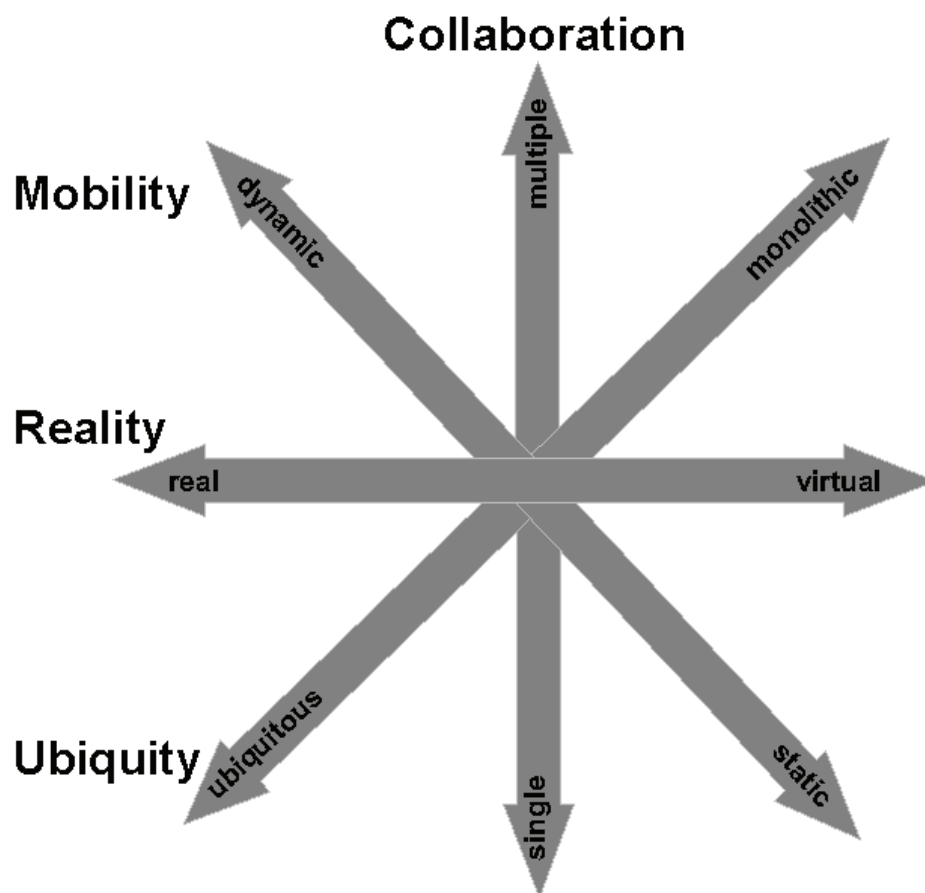
Figure 3 - Multidimensional continuum spanning a design space

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* and the *Urban Sketcher* … MRIML on the other hand is a markup-language for MR user interfaces.

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 3 Prototypes

The year 2 initial prototypes have been re-designed, developed, tested and evaluated according to D1.9 *Detail work plan for Month 25-42* (see Figure 4). Hence the work for each prototype is described in relation to the different phase, after a general introduction the review and re-design phase is describe, followed by the development & research phase and finally the testing and public demonstration phase as well as the evaluation phase.

Based on the second year prototypes developed in the work package Cross-Reality Interaction and Authoring Tools, we received feedback from the showcases for further developments. Additionally, based on this feedback and test results and observations all tools have undergone a re-design process. As outcome of this process, some tools only need to add functionality, while others need major code restructuring for better portability. All design decision taken can be found in the following sections.

Apart from the re-design process we have also decided working on two new authoring and interaction tools requested by the showcases.

The Multi-Touch Display – a large interactive display surface – is now addressing the new topic of Environmental, but is also doing collaboration with the Urban Renewal showcase demonstrators (The technologies were demonstrated together at the European City of Sciences exhibition in Paris, 2008).
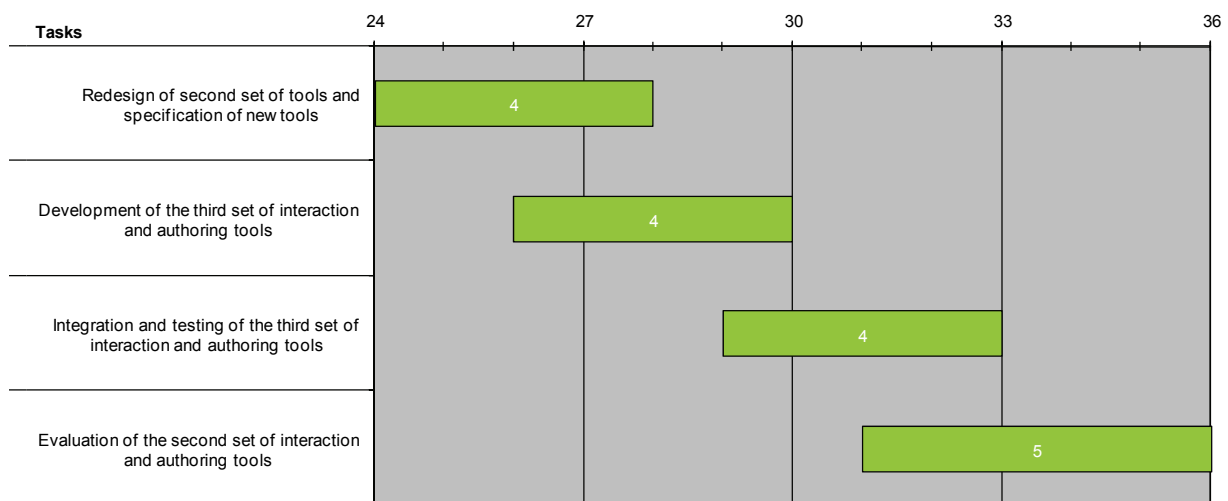
Figure 4 - Detail work plan for Month 24-36.

5.1   Interaction Prototyping

5.1.1   Redesign decisions

In contrast to year 1 and year 2 significant less re-design decisions were necessary in the recent 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 several 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 new features have been added to support the user and speed up the process of development.

Additional components

Since the second year prototype several new components has been added to enhance the usability of Interaction Prototyping. Additional, several components has been extended during the intensive use in e.g. TimeWarp (WP8).

Thus, we developed a new component able to simulate a common state machine. The *StateMachine* component holds an arbitrary number of single states with conditional transitions between them. Each machine starts in an initial state and tries to go from one state to another one. Depending on the local fields all conditional transitions of the recent state are evaluated. If a transition is fulfilled the component follows it and migrates into the new state. Therefore, the *StateMachine* provides a powerful tool for application logics with changing circumstances or states.

To provide the user with more algebraic functionalities we additionally extended the field types with more member functions. Now, vector or matrix types provide all essential methods needed in linear algebra like e.g. matrix transposing and inverting or vector length determination. Furthermore, we defined several global functions and constants speeding up the development time of prototypes for new VR/AR applications.
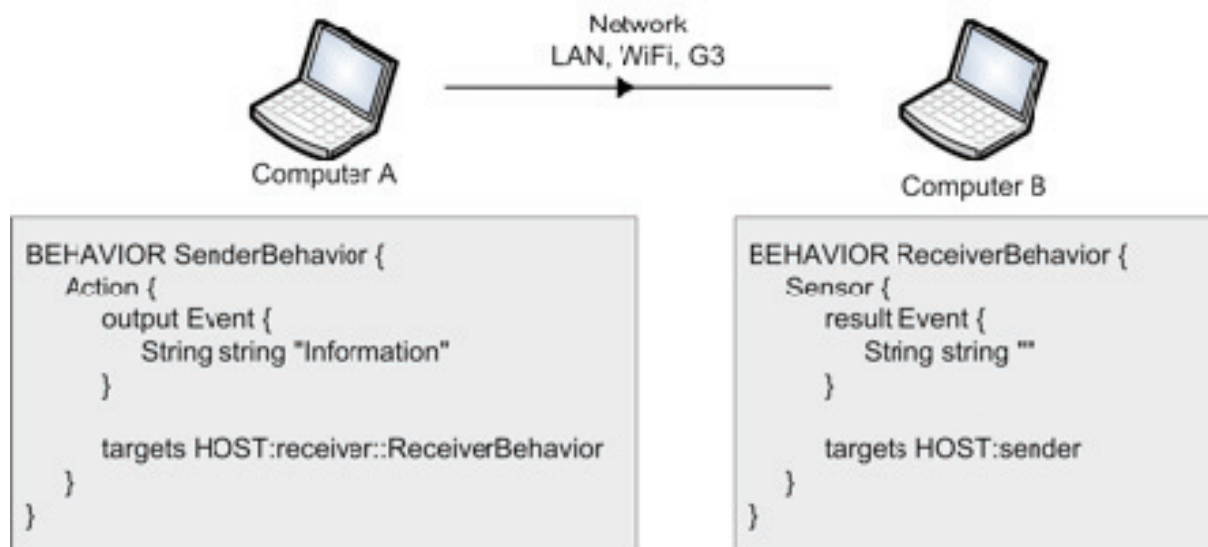
Network events

As a general rule each VR/AR applications can be applied in a multi-user environment. However, in contrast to single-user applications multi-user applications, the realization needs much more development effort. Often a large amount of data has to be shared between the users. Thus, based on the second year prototype we saw a big need for the exchange of data packages between distributed behavior engines. Therefore, we extended the event concept allowing data exchange not only between local behavior objects but also between distributed applications. The extension allows two remote behavior engines to share common data using an arbitrary network. The new concept provides the user with a powerful tool for multi-user scenarios while hiding the complex network structure. The data exchange is done by a normal *Event* and already existing *Action* and *Sensor* components. In comparison with a standard event delivery the user only has to specify the name or address of the receiving host additionally. Currently, Interaction Prototyping uses the UDP or TCP/IP network protocol for data communication. Figure 5 shows a simple example of the new network events.

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*.

Inheritance

In object oriented programming languages object inheritance is a common tool to reduce the amount of source code and development time. Therefore, we also added a powerful inheritance mechanism. Inheritance enables the user to enhance the functionality of already defined behavior objects or to change specific parameters and objects inside the components. In combination with the existing include mechanism the development time of behavior objects can be reduced significantly. The inheritance mechanism for behavior objects allows the following manipulations:

- Insertion of new components providing new functionalities

- Insertion of new fields into components which are already defined in parent behavior objects

- Modification of field values defined in parent behavior objects

- Insertion of new data and signal connections between new or already defined components

A simple code example of the inheritance mechanism is given in Figure 6.

```
BEHAVIOR FatherBehavior
{
      Sensor MOUSE_SENSOR
      {
          result Mouse {}
          targets VIEWER::Mouse
          CONNECT result.position.x FIRST_ACTION.output.string
          SIGNAL fire FIRST_ACTION.execute
      }
      Action FIRST_ACTION
      {
          output Event
          {
              String 1D string []
          }
          targets X3D::TEXT
      }
}

BEHAVIOR ChildBehavior : FatherBehavior
{
      MOUSE_SENSOR
      {
          CONNECT result.position.y SECOND_ACTION.output.string
          SIGNAL fire SECOND_ACTION.execute
      }
      Action SECOND_ACTION
      {
          output Event
          {
              String 1D string []
          }
          targets X3D::SECOND_TEXT
      }
}
```

Figure 6 - Behavior objects demonstrating the inheritance mechanism

The *FatherBehavior* object grabs the continuous mouse position by a sensor component. The sensor passes the x coordinate of the mouse position to an action component holding an event with a string array as output. Afterwards, the event will be sent to a defined X3D text node registered in an arbitrary X3D scene graph. The *ChildBehavior* object inherits all components from the *FatherBehavior* object and holds a new action component. The new action component receives the y coordinate of the mouse position and sends the value to a second defined X3D text node. Both the *FatherBehavior* and the *ChildBehavior* are fully operational behavior objects. However, the *ChildBehavior* owns the functionality of the *FatherBehavior* and has a second event output additionally.

Debugging and error messages

Another improvement has been done to provide debugging functionalities and more helpful error messages. The more complex the designed application logic, the more difficult troubleshooting can be. Therefore, more detailed error message are given if behavior objects contains e.g. a faulty syntax or unknown include files. These messages significantly reduce the time to find and remove the error.

Furthermore, now the user has the possibility to track the values of specific parameters inside behavior objects and components. Thus, the developer knows the values of interesting parameters at each time and can detect possible problems much faster.

Visual Interaction Prototyping Editor

Based on feedback from showcases, in particular WP 8, we extended the editor capabilities with support for the new Interaction Prototyping capabilities outlined above. Further, some preliminary informal user tests revealed a number of issues regarding usability. As an immediate improvement, connections between components can now be created using a point-and-click paradigm, rather than using drag and drop of a connection line to the interface.

Additional extensions and improvements are in the design phase as well. In particular we are considering extensions to the editor view, possibly allowing hiding of parts of components that are unused. Other considerations include the continued improvement of connection editing. We are currently studying various concepts, but results are only expected within Year 4. Eventually, the editor will also be extended with automatic connection routing, but this feature is in a pre-development stage as well.

In summary, the editor improvements will primarily be evolutionary. We are limiting major changes to the usability at this point in the project primarily due to consideration for the showcases. Major changes in usability of the editor always require some relearning for users of the editor in showcases of WP 8 and 9. Frequent relearning is not desired by users of the showcases as they need to achieve their goals rather than test new editor features while working on their showcases. As such, we are careful when extending the editor and put higher priority on extensions that do not fundamentally alter the user experience.

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   AuthOr

AuthOr is a service to augment arbitrary maps with 2D graphical overlays, e.g. lines, images and text. Depending on the application scenario this service can be used for supporting the whole process chain of creating, authoring, orchestration and directing mobile MR applications (see Figure 7).

Traditional computer games do not relate in any way on the environment in which they are played, no work has to be done to setup the game or adopt it to the local environment the same applies to other MR applications using a fixed installation. This is not the case for mobile MR applications, thus the developers have to cope with new challenges. In particular, although the application design might be independent from the actual environment – the real world location – actions, items, events and virtual characters have to be closely integrated and require a strong relation to the current real environment. Such pre-runtime configuration and setup is known as orchestration and is an essential part of a mobile MR application. In

case the mobile MR application has an event like character – where the users are equipped with special technology and the environment needs to be setup as well – it is also very crucial that such adaptations to the application can be performed during a session in order to influence the user interactions. Here we use the term direction for in game monitoring and adapting the user interactions.

AuthOr helps the developers to meet the challenges of orchestration and direction for mobile MR applications. Usage of AuthOr is not limited to the developers, but also can become a part of the application itself – e.g. TimeWarp – and hence support the whole process chain of creating authoring, orchestrating and directing for mobile MR applications.
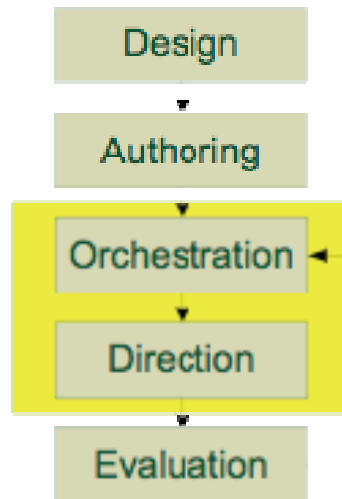
Figure 7 - The process chain of creating mobile MR applications. It is an interactive process after the design and the authoring phase, the application is tested and evaluated, afterwards, it is adapted again.

5.2.1 Redesign decisions

The authoring and orchestration tool AuthOr is used extensively in the WP8 (TimeWarp) showcase. Based on the feedback from this showcase, we determined that the 2D capabilities of AuthOr (Figure 8) are sufficient for the deployment of the showcases in current environments that are well known to the showcase designers. However, the AuthOr interface does not easily permit redeployment of the showcase to new locations. The deployment of the showcase in new locations is not supported well enough by AuthOr and its 2D capabilities. These capabilities, while interactive, do not allow control within a 3D environment.

Figure 8 – Example of AuthOr used in the TimeWarp showcase.

We are planning to use the concepts of AuthOr and extend them by adding 3D support, making the tool more useable for redeployment of the showcase (i.e. in New Zealand in cooperation with the new project partner HITLab NZ). The design of these changes has already started, however, work on the development and implementation will take place within Year 4 and the remaining time of the project. This work will be partially supported by the IRSES researcher exchange project MARCUS (FP7–PEOPLE–IRSES–2008-230831).

5.2.2   Development & research

Our primary focus in the continued development of AuthOr was on stability improvements and bug fixing. In addition, we began to development of the companion software to use AuthOr in a 3D environment. The goal of the companion software is the development of an interface for AuthOr and its display capabilities within the Morgan framework. The development is expected to be completed in mid-2009 and is expected to be used within WP 8 and possibly WP 9 in conjunction with the integration of a KML (or similar technology) XSG developed in WP 5 into the Morgan framework.

5.2.3   Related Work

Although MR Games have been developed for a couple of years, there are a lot of examples where the game does not relate to the environment or it has been set up for a specific environment. An example for environment unrelated games is *ARQuake* [Piekarski2002] and *ARPacman* [Cheok2004] for a fixed location game.

The mobile SMS game *Day of the Figurines* the staff managing and leading the game, used orchestration in order to manage and track the production of game play narratives during the game session. They state that orchestration is inseparably intertwined with the game play [Cabtree2007].

Epidemic Menace [Lindt2006], a cross media pervasive AR game, used orchestration tools for pre-game setup and in-game adaptations. In this game two teams have to fight a spreading viral menace. While the outdoor players have to fight the virus, the indoor players have the overview of the game are and communicate that to the outdoor players.

A good overview about the technology challenges of pervasive augmented reality games is given by Broll et al. [Broll2006], where the different aspects are closely reviewed and solutions are presented.

Broll, W., Ohlenburg, J, Lindt, I., Herbst, I, and Braun, A.-K. *Meeting Technology Challenges of Pervasive Augmented Reality Games*. In Proc. of ACM SIGCOMM NetGames 2006, 2006.

Cabtree, A., Benford, S., Capra, M., Flintham, M., Drodz, A., Tandavanitj, N., Adams, M., and Farr, J.R. *The Cooperative Work of Gaming: Orchestrating a Mobile SMS Game*. In Computer Supported Cooperative Work, 16(1-2), 2007.

Cheok, A., Goh, K. H., Liu, W., Farbiz, F., Fong, S. W., Teo, S. L., Li, Y., and Yang, X. *Human pacman: a mobile wide-area entertainment system based on physical, social, and ubiquitous computing*. Personal Ubiquitous Computing, 8(2), 2004.

Lindt, I., Ohlenburg, J., Pankoke-Babatz, U., and Ghellal, S. *A Report on the Crossmedia Game Epidemic Menace*. ACM Computers in Entertainment (CIE), 5(1), 2006.

Piekarski, W. and Thomas, B. *ARQuake: the outdoor augmented reality gaming system*. Communications of ACM, 45(1), 2002.

5.2.4   Testing and public demonstration

AuthOr is used extensively within the showcase WP 8 (TimeWarp). New work on the 3D extensions is underway and has not been tested or demonstrated yet.

5.2.5   Evaluation

Evaluation of the MIT was more focused on presence aspects and no user studies have been conducted regarding the AuthOr part of the MIT.

5.2.6   Specification

Hardware and OS	Windows XP, Windows Mobile 5, Windows Mobile 6
Software	C/C++
Core Features	- Access to Google Earth tiles - Access to Google Maps tiles - Access to Virtual Earth tiles - Hybrid mode - Overlay support - Lines - Images - Separation of core functionality and GUI and OS specific functionality
Status	Stable prototype, which will be further developed.
Intended users	Showcases and tools developer
Showcases	WP 6, WP 7, WP 8, WP 9
Relevance beyond project	The tool is developed as a general tool, that can be used outside of the project.

5.3   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 tools that are developed in year 3 are based on the prototypes of year two. Extensive work has been done to integrate the different components into a same place and workflow. To achieve this it was necessary to plan and construct a 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 3 are the colored objects interface, the barcode interface including the content cards, the rotating viewpoint and the billboard sketcher.

5.3.1   Redesign decisions

Based on the preparation for the two workshops in 2008, the feedback of the years 1 and 2 the ColorTable was once more exposed to different decisions on development and redesigns.

5.3.2   Workspace organization

The high number of new interaction modules of the ColorTable stressed the importance of organizing the workspace. All the material and devices needed should be within reach but not in the way. We resolved these users' problems with the integration of rotating viewpoint and tangible selector directly into the hardware of the table. Additional workspace has been developed as two retractable side frames for placing tokens and the barcode trays. (see Figure 9)

Figure 9 - A solution for better organizing the workspace

5.3.3   The physical ColorTable

To simplify the set up inside and around the ColorTable and to achieve a supporting workspace we designed and constructed a physical ColorTable. The physical table is wooden and consists of (see Figure 10):

- One wooden round tabletop (diameter: 120) with prefixed foam rubber underneath to predefine the exact place for the mouse (for the rotating viewpoint) and the RFID reader (for the tangible selector).

- Two wooden foldable parts setting the four stable side frame for the table fundament.

- Two wooden retractable storage frames mounted at the table fundament.

Figure 10 - Physical ColorTable; including rotating viewpoint, tangible selector and barcode reader

To restructure the workspace and make the technical overload invisible for the users, we decided to place inside the ColorTable:

- Server

- Printer and A4 paper

- Hardware of viewpoint rotator and tangible selector

- USB and serial Hubs

- Related cables

5.3.4   Flows and Connections

Major changes have been made with the flows. We also added a way-optimizing algorithm that calculates the shortest/cheapest paths between arbitrary points in the networks of our

connections. Two special tokens are placed on the map and mark the start and endpoint of the route, while an additional configuration-area allows adding extra waypoints to the path that need to be visited. The colors in the configuration-area correspond to the colors of the programs (assigned by the user).

To decide on the types of transport, speed and concurrency, users can define different types of connections and populate them with flows by setting a start and endpoint. Solid rectangular tokens define the endpoints of the connections with the color determining its type e.g. highways, roads, footpaths and rivers (see Figure 11).

Figure 11 - Flows automatically start as soon as streets are in the scene

5.3.5   Tangible selector

We resolved users' problems with the configuration areas by integrating the workplace for selecting objects into the physical ColorTable. The tangible selector (see Figure 12) consists of several disks, on which all the available color objects are represented as flat colored illustrations and explained in Braille language for blind users. When a certain object is selected, the RFID is captured by the reader and used as input for the Input interpreter, a component responsible for the communication between RFID and Barcode based interfaces and the Muddleware server.

Figure 12 - Integrated tangible selector

5.3.6   Billboard Sketcher

We further developed a tool allowing users to add their own paper sketches to the Hypermedia Database. It includes a surface, where users can sketch with a conventional pen on an A4 sheet of paper, and a web cam, placed above the surface, capturing the content. The tool automatically crops the background and stores the result in the Hypermedia Database in order to be available for other applications such as the barcode interface. The billboard sketcher provides means to create new billboards by drawing with conventional on

sheets of paper. The drawings can then be framed with a digital frame to be added to the mixed reality scene.

The billboard sketcher (see Figure 13) consists of…

- One wooden plate with a defined black area for placing the sketches
- One mounted Logitec web cam to capture the sketches
- Two simple lamps to light the sketch and enable the capturing
- Seven barcodes to choose the picture frame, the size and sending it to HMDB

Figure 13 - Adding paper sketches to the HMDB with the billboard sketcher.

5.3.7   Redesigning the color objects

Due to the trials and user workshops we took part, the development team at TUW decided to emphasis more on the physical objects and make an new concept for the color objects as well a redesign them.

Tokens Version 1

To meet the feedback of the workshop from 2007 new color tokens in form, material and size were designed and built. The tracking color itself does not longer represent a specific content e.g. the height or volume of a building. This decision was made after the first workshop, as the users called for more content. We met the challenge with a fixed number of 20 basic, cylindrical tokens and 40 tracking color discs (each color of the 8 predefined tracking colors has 5 discs).

A white sticker at the side face of the cylinder was giving room for annotations with a pen. The idea was that, users might want to make notes to remember thoughts and important comments in the discussion regarding specific media (see Figure 14).
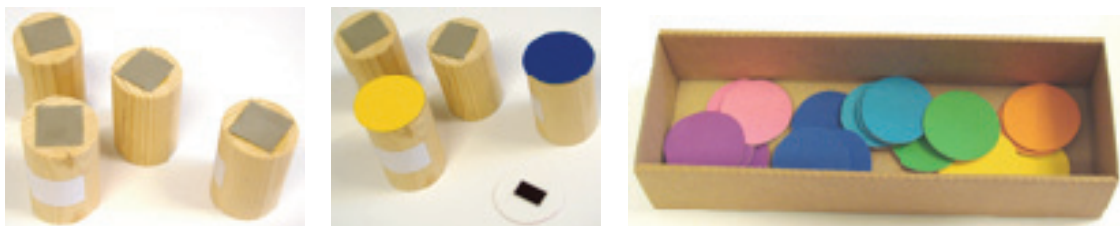

Figure 14 - Basic tokens; attached tracking color tokens, tracking color tokens

For specific interactions the user needs two square tokens to set the beginning and the end of a connection (see Figure 15). A second pair of wooden squares provides a "Trip" shown

as flows in the panorama view. The user gets and impression about the placed connections in the scene and gets help to evaluate them.
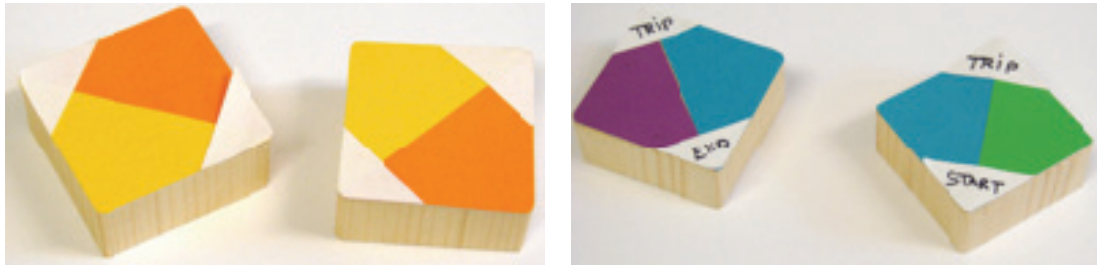
Figure 15 - The special tokens: Pair of connection tokens, pair of trip tokens

For this prototype we also improved the barcode trays in adding some little icons next to barcode text for faster understanding what it is for. Together with the appropriate barcode photos of little rectangle cards represent the media content (see Figure 16).

Figure 16 - Barcode tray with icons, magnetic content

Tokens Version 2

New formal and material design issues are the bases for the redesign of the tokens in version 2. We redesigned the tokens once more to meet additional requirements. To foster tactile guidance we used various materials and forms representing different type of content. The tokens are formally split into different graspable object with a tactile, attractive material (for these experiments we tried out wood, Plexiglas and cork) to give some fast hint for the use and category of content. The tracking color itself is attached to and represents a specific content. Generally the size of the tokens is reduced comparing to all former tokens. The use of two basic geometric object forms (circular, rectangular) and the difference of token size and volumes are integrated in these experiments (see Figure 17).
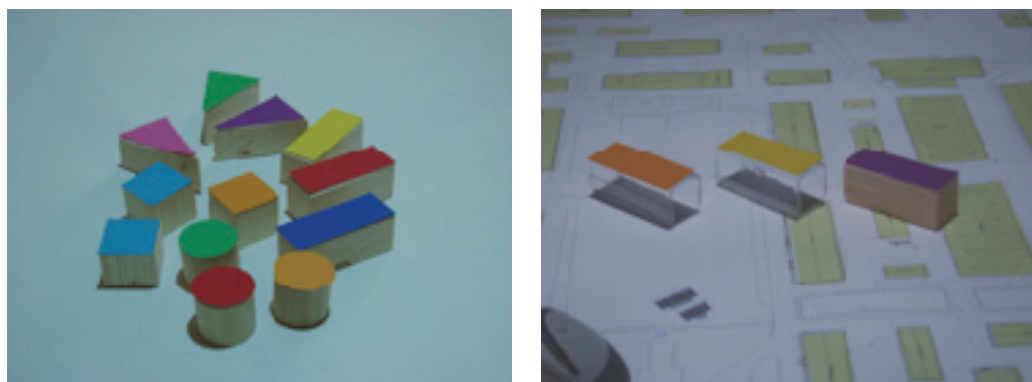
Figure 17 - Different material and forms

Additional annotations (texture printouts) were mounted at the side frame of the rectangle and the round tokens to make the use easier. The Plexiglas tokens have their use "Flows start" and "flow end" printed at the side.

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 in three different manners by activating a different mode. Users can select the camera position as hearing position and listen to the sound which corresponds to the panorama or video feed. Another possibility is to bound the hearing position to a flow; hence the resulting sounds cape corresponds to the path of someone moving with the flows. Finally, the hearing position can be set by placing the red triangular token, defining the virtual listener's position and orientation.

5.3.8   Additional 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.

Assigning Programs

Different programs are represented on content cards with images and corresponding bar-codes. They allow the users to assign billboards or 3d-objects to colors of their choice. As usual the content is selected via the bar-code-reader, while the tangible selector is used to choose between the different colors. We developed a content tray, where the users place their content cards according to the tracing color (see Figure 18).

Figure 18 - Small content cards on content tray

Monitoring System Feedback

Due the limitations of the different connection-types, the paths are optimized for every kind of flow separately (car, bicycle pedestrian). The Info Screen displays the distance and approximated time for each flow-type to allow more detailed analysis of the designed connection network. The footprints of the programs, the connections and the individual flows are displayed directly on the physical map, while the visual representations of these in 3d-space appear on the panorama-projection that can be rotated as usual (see Figure 19).

Figure 19 - Info screen, foot prints and panorama-projection provide visual feedback and representations.

Defining Use

For the rapid definition of land use we use an automatically computed Voronoi decomposition using circular tokens, put by the users as anchor points. While the top view projection shows the borders of each Voronoi polygon in wireframe, the cells in the egocentric view are textured in an abstract manner to represent the corresponding land use. Eight colors are reserved for different types of land use, the corresponding texture is illustrated on the side of each token (see Figure 20).

Figure 20 - Automatically computed Voronoi

Working with Persistency

The composed scene can be stored anytime by invoking the "freeze" barcode. All color tokens currently placed on the table are permanently added to the scene and saved as a new instance in the history application. Also all the corresponding tokens are freed and available for arbitrary use now. A once frozen object can only be removed with the eraser token (red rectangle). Barcodes allow users to step through the design process and examine or even change all frozen states. The history function does not only allow to go back in time to a previously obtained interesting state, but also allows to use temporality as part of the inspirational process by looking at the evolving scene over time. Freezing a scene is also a good idea before changing physical maps, because once frozen objects are scaled properly and remain at their absolute spatial positions.

Printing

Users can take snapshots of their compositions at any time. The current exocentric and egocentric views are then saved as images and automatically printed for later reference. **Screenshots** of the composed scene are automatically taken in a specific interval of time.

Sketching

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).

5.3.9   Implications for Redesign

The material artifacts we have designed take a key role in this process. We made use of different materials (wood, Plexiglas, cork) to distinguish the different types of tokens. An additional layer of transparent paper placed on top of the buildings supported haptic orientation on the site map. The prototype fosters the visual and haptic revisable difference. Some of the re-design we undertook simplified the use of the objects. Hence, the design has to specified and intensified further on this matter.

Important issues for re-design are:

- Continue to investigate the user's chains of action with the various objects and tokens to gain a deeper understanding of interaction.

- Provide other possibilities for the user to make annotations

- Simplify the workspace and provide additional desks for working with the objects

- Experiment with various materials and surfaces.

- Further develop the idea of basic tokens forms to give a visual and haptic guidance and clues for usage.

- Further simplify the interface and the interactive objects, especially reduce the additional devices and objects around – create a clear environment

The interaction research questions are:

- How can we further optimize interaction for users? How can basic tokens provide further visual and tactile guidance?

- 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?

5.3.10   Related Work

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.

Ishii, H., Ben-Joseph, E., Underkoffler, J., Yeung, L., Chak, D., Kanji, Z., and Piper, B. *Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models and Digital Simulation*. In Proc. of Ismar'02. ISMAR. IEEE Computer Society, Washington, DC, 203, 2002.

Mazalek, A., Davenport, G., and Ishii, H. *Tangible viewpoints: a physical approach to multimedia stories*. In Proc. of the Tenth ACM international Conference on Multimedia, Dec 01 - 06, 2002, Juan-les-Pins, France, MULTIMEDIA '02. ACM Press, New York, NY, 153-160, 2002.

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.

5.3.11 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 2 different workshops and 1 exhibition during phase 3:

- Experimentation with simple rules commonly used in urban planning in Vienna; June 2008.

- Workshops in Cergy-Pontoise with stakeholders and urban planners; September 2008.

- Exhibition within the European City of Science in Europe; November 2008

5.3.12 Specification

Hardware and OS	6x Laptop, Desktop, 2x Projector, Webcam, UrbanSketcher, Flatscreen, Barcode Reader, ColorTable , Windows XP
Software	ColorTable framework, Muddleware, Studierstube, Open Tracker, Tomcat, HMDB
Core Features	Voronoi segmentation, Connections, Flows, 3D Lines, Saving and Loading, Printing, Sketching
Status	Gamma prototype
Intended users	Stakeholders
Showcases	For all interested showcases and is used in WP6
Relevance beyond project	Development of user interfaces to support the challenge of collaboration, user content preparation and embodied interaction modes.

5.4 MapLens

MapLens is an application for Symbian OS S60 Nokia mobile phones with camera and GPS. 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). 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 (Figure 21)

Figure 21 - MapLens in use with a paper map.

5.4.1   Redesign issues

Currently the tool relies on a 3rd party tool called ShoZu in uploading the photographs taken with MapLens. ShoZu uploads the photos to Flickr service with special tags. Then a component developed by UOulu fetches the photos from Flickr using Flickr API and the tags to HMDB. Then MapLens uses the KML export feature of HMDB to get the content to the phone. This extra step consumes resources on the device, slows down the sharing of the media and requires extra components (ShoZu, Flickr, importer) which are hindrance to the reliability of the system. Since for MMC there already has been developed a HMDB upload component on Symbian phones, as well as a GPS module (used by ShoZu), these two modules can replace this setup of using ShoZu, Flickr and the importer. This work is now ongoing development.

5.4.2   Development & research

MapLens application is developed with C++ on Symbian OS v9. The application functionality is as follows:

1. Acquire the image of the map from the camera of the phone.

2. Analyse the camera image, extracting key features from the image.

3. Match the key features of the map to a database of features prestored on the mobile phone.

4. By using the feature database and the features of the visible area of the map, define the GPS coordinates of the corners of the map shown.

5. Extract the location based data from an external database (the HyperMedia Database; see WP5) and displaying layered icons and media on top of the visible area of the map for the user.

6. Enabling the user to select visible overlayed data and viewing the details of data.

7. Enable the user to take snapshots of the camera viewfinder, where the snapshots are then tagged with GPS location and uploaded to the HDMB.

As the user moves the camera over the map, the content thus changes, depending on the area visible on the phone screen.

The image analysis is implemented in two complementary components. One component uses tags places on the augmented map for fast analysis. Another component does not need augmentation, but uses the features of the map (roads, rivers, any other distinctive elements on the map) for feature identification. The first trials were conducted with the first implementation, as the current version relies on the second version which is also still optimized. Further trials are done with the second version.

The location specific media on the maps are fetched from the HMDB using the APP (Atom Publishing Protocol) interface of the HMDB, over HTTP protocol. The data format the HMDB provided is KML (http://code.google.com/apis/kml/). The media files are included in the KML file as hyperlinks to the media stored either into the HMDB or elsewhere on the Internet. The media files are fetched onto the phone after receiving the KML file.

The role of the HMDB is to act as a cache and a single source for the location based data displayed on the layers of the tool. Actual media and other data may either be directly stored by other applications to HMDB (like MMS Entrance, Bluetooth Media Dispatcher, eMailEntrace or other tools).

5.4.3   Related work

The concept of magic lens was first introduced by Bier et al. (1993) as a focus+context technique for 2D visualisations and was later extended to 3D by Viega et al. (1996). The NaviCam system by Rekimoto (1997) introduced magic lens on hand-held displays (see also Cao et al. 2008). Later on, mobile AR has been explored also with peephole interaction where the background surface is used for positioning the phone in virtual space (Henrysson et al., 2005).

Research in AR for paper maps has explored a wide range of output modalities. McGee et al. (2000) augmented a real map by automatically locating post-it notes placed on it to keep a computer model up-to-date. Bobrich and Otto (2000) used head mounted displays in a video see-through AR setting to present 3D overlays of digital elevation models over a real map. A projection-based system by Reitmayr et al. (2005) augmented a paper map directly with dynamic, geo-referenced information. Transition to mobile devices has placed special demand on lightweight methods of localising. Reilly et al. (2006) used RFID tags to associate locations on the map with digital information. Rohs et al. (2007) describe computer vision-based method using sparse fiducial markers on a map.

User trials of any kind for mobile AR are scarce. Henrysson et al. (2005) piloted positioning and orientation of 3D virtual objects using a mobile phone. They observed that the users sat down rather than stood up in order to stabilise the phone in hand. Reilly et al. (2006) reported a laboratory study where subjects performed pre-defined tasks on an RFID versus non-augmented PDA version. Usability depended on the size of the map, information tied to it, and the task of the user. The authors point out that the tasks required little or no spatial knowledge as the trial was conducted in a single location and involved no routes, land-marks, or navigation. Rohs et al. (2007) compared map navigation between joystick, static peephole and magic lens interaction. The study showed switching of attention between the surface and background affects task performance, yet static peephole and magic lens clearly outperform joystick navigation.

Laboratory based studies have shed light to some aspects of mobile AR based interaction, but we find three critical aspects still need to be addressed: 1) interaction while embedded and mobile in the referred-to environment; 2) inter-action in pairs or teams; and 3) suitability of mobile AR maps for real world use. Furthermore, typical laboratory experiments do not involve interruptions, involve very brief tasks, are completed by individuals, and do not involve physical aspects of the environment. (Rohs, 2007.) Conversely, the trials conducted by us lasted 1.5 hours, involved a variety of inter-related and sequential tasks, and teams

needed to interact with the physical environment as well as with other people in order to succeed in the game.

Bier, E., Stone, M., Pier, K., Buxton, W., DeRose, T., *Toolglass and Magic Lenses: The See-Through Interface*. Proc. SIGGRAPH '93, ACM Press (1993), 73-80.

Bobrich, J., Otto. S. *Augmented maps*. In Geospatial Theory, Processing and Applications, Proc. ISPRS Commission IV, WG7, (2002).

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

Henrysson, A., Ollila, M., Billinghurst, M. *Mobile phone based AR scene assembly*. Proc. MUM 2005, ACM Press (2005), 95-102.

McGee, D. R., Cohen, P. R., Wu, L. *Something from nothing: Augmenting a paperbased work practice via multimodal interaction*. Proc. DARE 2000, ACM Press (2000), 71–80.

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

Reitmayr, G., Eade, E., Drummond, T. W. *Localisation and interaction for augmented maps*. Proc. ISMAR 2005, IEEE Press (2005), 120–129.

Rekimoto, J. Navicam: *A magnifying glass approach to augmented reality*. PRESENCE - Teleoperators and Virtual Environments, 6(4). MIT Press (1997), 399–412.

Rohs, M., Schoening, J., Krueger, A., and Hecht, B. *Towards real-time markerless tracking of magic lenses on paper maps*. Proc. PERVASIVE 2007, 69–72, ACM Press (2007).

Rohs, M., Oulasvirta, *A. Target acquisition with camera phones when used as magic lenses.* Proc. CHI '08, ACM Press (2008), 1409-1418.

Viega, J., Conway, M. J., Williams, G., Pausch, R. *3D magic lenses*. Proc. UIST '96, ACM Press (1996), 51-58.

5.4.4   Testing and public demonstration

The MapLens application was tested extensively in WP7: first field trial was held in March 2008 in Helsinki with 5 users and a series of next three field trials took place in August 2008 in Helsinki with a total of 37 users. In our trials we enlisted a mix of 37 early-adopters, environmental researchers, scouts and their families to use MapLens, to play an environmental awareness-raising location-based game. A comparative trial was run with a non-AR digital system called DigiMap.

5.4.5   Evaluation

Analyses of videos, field notes, interviews, questionnaires and user-created content expose phenomena that arise uniquely when using AR maps in the wild. We noticed how augmentation affects the way participants use their body and hands, manipulate the mobile device in tandem with the physical map, walk while using, and collaborate. We found that the MapLens solution facilitates place-making by its constant need for referencing to the physical, and in that it also allows for ease of bodily configurations for the group, encourages establishment of common ground, and thereby invites discussion, negotiation and public problem-solving. Its main potential lays not so much in use for navigation but in use as a collaborative tool.

5.4.6 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 HMDB.
Status	Implementation ongoing, second prototype ready by 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.

5.5 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.
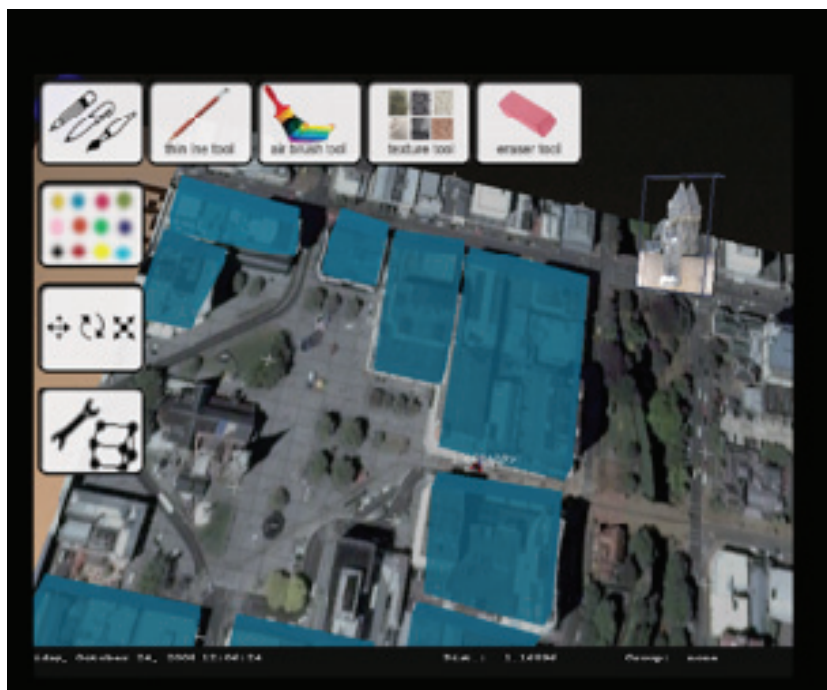

Figure 22 - 2D Menu overlay for tool selection

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.

5.6   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 enables 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.

5.6.1   Redesign issues

MMC has now reached the first prototype version. 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 current first prototype includes the following features:

- Recording geotagged voice notes.

- Taking geotagged photographs.

- Uploading the recorded media to the HMDB using Atom Publishing Protocol and HTTP.

- 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.

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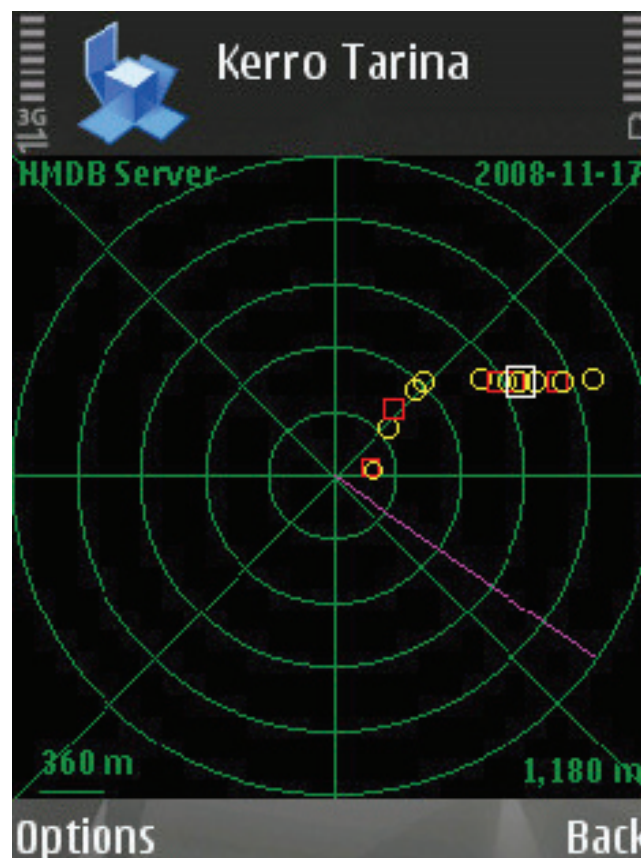
Figure 23 - The Radar view of MMC (Kerro Tarina; Tell-a-Story), showing sound files (circles) and photographs (rectangles) downloaded from HMDB.

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.

Depending on the showcase needs, the following features are next on the implementation list:

- Based on the first tests and trials (see 5.6.5) the interface for recording stories and taking pictures needs to be revised for better usability;

- 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

- Improvements of showing the collected media in the design studio (KML, Google Maps/Earth, or other tools for viewing the HMDB content).

5.6.2   Development & research

There are many aids designers use in assimilation of the context and environment. Often designers use aids such as maps, aerial or satellite imagery, sketching and photographs (Figure 24) to memorize and collect the experience of the site for further reference. These are then later used in the studio to "revisit the site".

Figure 24 - Using photographs and sketches on maps in design.

The material that was collected, including photographs, maps and also sketches perhaps made on top of photographs and maps, is used in the process (Figure 25). In the design, unrelated buildings, areas or sites can also be used as a reference. An unrelated building from a completely different context, even far away, can "give the feeling" of the intended design solution. This kind of inspirational material can also complement the material collected from the site.

Figure 25 - Sketching on maps, early phase of design.

The initial design principles and ideas may also be reflected against the real, concrete environment by re-visitations accompanied with sketches. This way the designer is able to find areas for improvement and see if the intended design solution would actually work or not. Especially in participatory design these initial sketches may also be discussed with the participants, either in the studio environment or at the site. For example, perspective drawings on top of the photographs from the site can be used to illustrate how a particular mass of buildings would fit a particular site.

5.6.3   The MMC tool concept

Before working on a specific design, the user is able to choose with which project she is working on. After this she can browse the maps, sketches and/or pictures or other media related to the project. Figure 26 of the mockup below illustrates the main feature of the MMC, the handling of location specific media and sketching over maps and photographs. Please note that the mockup size and layout is just used to characterize the functionality included in the concept – actual device can also be, for example, a smart phone.

Figure 26 - The Field sketcher map and media view.

In the figure above, the designer has selected a photograph of a specific place using the icons on the map, and is currently sketching on the photograph. Both the map and the photo can also be viewed full screen, giving room for the browsing, viewing and manipulation.

The MMC can be used when traveling to the site (Figure 27). The designer can view the site map; plan the interesting places to visit and to take photographs of. In a collaborative setting, designers can negotiate on who goes where and what are the commonly interested sites and perspectives of the designers on the design task. If the car (van) has a flat display panel installed, the designers can share this in presenting their initial ideas for the visit, as well as when returning, discuss their afterthoughts.

Figure 27 - Planning the site visit using MMC in a car.

An important part of the visit is the collection of different types of media. The media helps the designer in grasping the essence of the site, by focusing on particular views and objects in the site from the perspective of the individual designer (see Figure 28). This media is location dependent. Also, it is important for the designer to be aware of perspectives and directions. The MMC supports these elements of grasping the site by storing the GPS location as well as the compass direction where the media was stored. The media can then be viewed in relation to the map, for example (see Figure 24).

Furthermore, the MMC is able to select photographs by GPS location, and then by analyzing the compass direction of the photographs in the same location, stitch these photographs into a panorama, giving a more comprehensive view of that location to the designer.
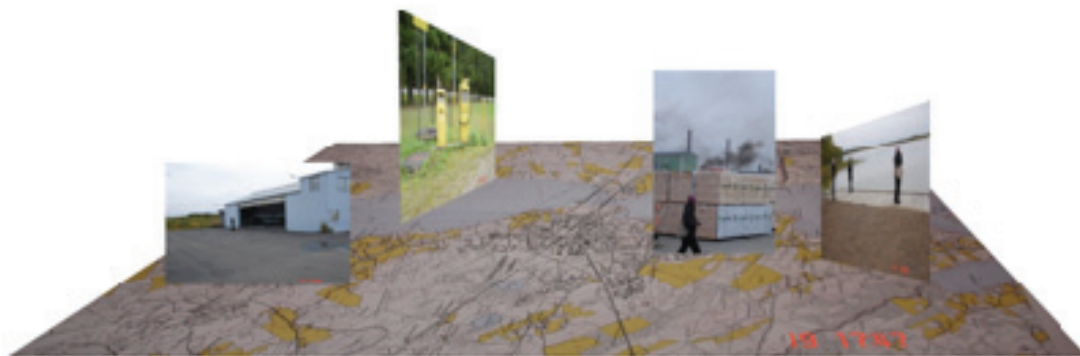
Figure 28 - Crude mockup of the view of location specific, directional media placed on map.

In the studio, or in the collaborative meeting with participants of the design, the MMC is used as the designer's tool for mediating her vision of the site and the possible design solutions. The output of the MMC is projected on a wall or to a large display (Figure 29).

Figure 29 - Presenting design ideas, views on a large display to stakeholders.

If many designers are participating in the process, the placemarks, and paths and associated media (photographs, videos, sound notes), notes and sketches can be shared wirelessly and displayed at the same time. Alternatively the presenter can focus on individual content or content related to some specific area. The large display acts as a common table for discussing the ideas and forces affecting on the design.

5.6.4   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.

5.6.5   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 30 - 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.

5.6.6   Evaluation

The data collected from the experiment described above has not yet been analyzed. Also other trials are also under planning at the moment. The MMC is also at this time under development after the first prototype. Further trials should be planned together with planning the future versions and timing of the development.

5.6.7   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	First prototype with limited features implemented and trialled.
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.

5.7   Multi-Touch Display

Multi-touch Display was developed further to meet the new demands for the new focus of WP7, environmental awareness. The principle behind of the technology is still the same: it supports creation of multi-touch screens that are several meters wide and located either indoors or outdoors and the system can be used simultaneously by several users. The system is based on computer vision in the near-infrared range (700-1000 nanometers) and the system is built to track hand movements on an interactive projection surface. It uses off-the-shelf components (FireWire cameras, lenses, filters, infrared illuminators) to track users fingers on the surface where the image user sees is displayed. A new addition to the physical installation is the use of mirrors: to be able to run the installation in a smaller space, the image to the screen is projected through a mirror. This way the projectors can be located underneath the screen.

To detect contacts against the multi-touch display infrared cameras connected to a PC are used. The computers runs 1) touch-display manager that captures images from the camera and calculates touch-points from the images using computer vision (CV) methods and 2) application layer (e.g. CityWall developed in WP7) that produces the part of that users sees and can interact with. The current touch-display manager was ported from Linux to Windows (still written in C++). The application layer has been totally rewritten and runs in C#. These redesign decisions are discussed next.

5.7.1   Redesign decisions

To support the new brief of environmental awareness and to answer issues raised in the review and the feedback received from the field trials a full redesign of the Multi-Touch Display framework was initiated.

The original Multi-Touch Display installation runs on the Linux platform. As such, the implementation is not easily extensible beyond photo browsing functionality, so the more complex requirements are not well supported in the existing code base. Furthermore, because the original application is quite intimately coupled with the low level Computer Vision software component developed in WP4, the adaptation process could not be directly based on the existing framework.

5.7.2   Development & research

A widget-based multi-touch SDK was developed for Linux and OSX platforms to address the issues described in the previous chapter, reusing most of the generic code of the original implementation. Although it is much more productive to work with the newly introduced widgets, it was seen that a considerable amount of time would be still invested in writing the trivial functionality. Because much of that triviality was already available in Windows platform, and because the development tools are more advanced there, the SDK was ported to Windows. The time invested into porting seems to be well spent, also when considering future extensions of the CityWall. The SDK port consists of 9 custom Dynamic Link Libraries (DLLs) and 14 third party software components, which constitutes a relatively complex solution environment. The large number of external dependencies arises from the differences in Unix- and Windows-based operating systems. To simplify the maintenance and deployment tasks, a native version of the port was devised, resulting in a solution that uses one merged custom DLL and two third party components. The enabler for the complexity reduction is .NET framework and Windows Presentation Foundation (WPF), which overlap and extend the functionality supplied by the initial port. Another benefit is in the support for further extensions, both in custom and in third party code base.

The current Multi-Touch Display Framework consists of following pieces:

- computer vision (CV) managed wrapper library

- TUIO/OSC and TouchLib interfaces

- input framework (interfacing CVs, events)

- output framework (2D+3D widgets, scene transformations)

- gestures: drag, stretch/pinch, rotate, tap + doubletap, hold, keyboard

- widgets: 2D photo, video, text, 3D applet, satellite, a Photo Plane (place where photos displayed)

- applets: started media wall and services/disservices browser

In summary, the current Multi-Touch Display framework is built on the previous code base, but runs now on top of Windows .NET/WPF layers. The Multi-Touch Display backend shall include also XMPP (for application to application connections), MMS (for mobile phones) and an optional RESTful HTTP interface, so that it will be possible to integrate components from other workpackages, if needed. See Figure Figure **31** for a more detailed overview of the Multi-Touch Display framework and Figure **32** for an overview of the interfaces provided by the framework.
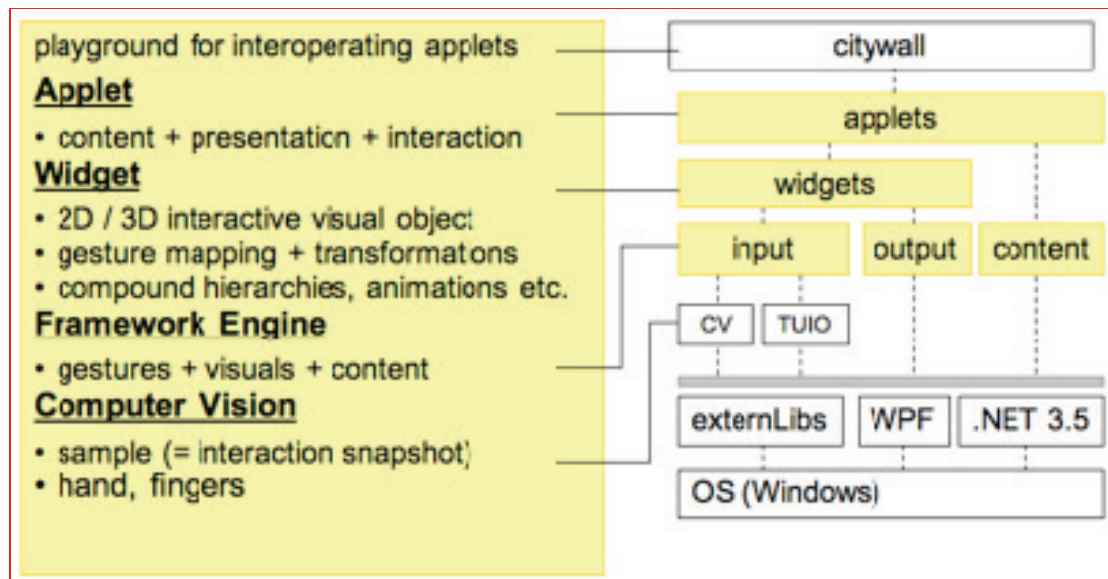
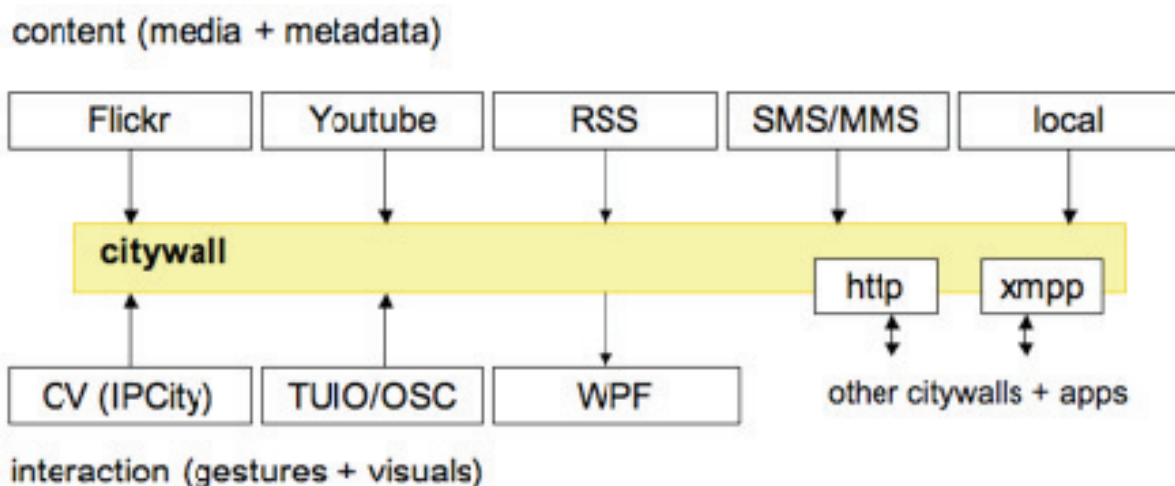**Figure** 31**. Multi-Touch Display framework.**

Figure 32**. Interfaces that Multi-Touch Display framework provides for the application layer (for e.g. CityWall).**

5.7.3   Related Work

Development and Theory of Language Paradigm

We have integrated an input language which enables:

    1. Recognized gestures

At the lexical level, the computer vision (CV) component recognizes blobs (i.e., continuous areas that exceed a preset threshold), interprets them as fingertips' xy-locations, and collects all recognized tips from a captured camera frame into a single data structure. This structure contains also further analysis data like fingers previous location, orientation, and grouping of fingers into hands.

At the syntactic level, the system gets a frame from CV and compares it with previous frames, in order to process the lexemes into finger down/move/up tokens. These form the alphabet of the input language but as the tokens are examined in time/space domain, one finds continuous sequences that form the set of recognized elementary gestures, or words of the input language:

These gestures (or words) can flow in a continuous interaction sequence (or sentence), fusing into other gestures as they go, and then back again. This fluidity appears more like singing than talking. Actually, many musical instruments (especially winds or brass) use basic gestures to initiate the sound, which later fluidly flows via modifying gestures to minute nuances or even radical expressions in audible domain. Using multitouch interaction is similar in some senses. (Smith Schraefel, 2004)

2. Widget gestures

The semantics or bindings of the gestures are defined by the output language elements below the touch points. Table 1 shows the recognized input gestures at the leftmost three columns, and the suggested 2D and 3D bindings at the rightmost ones. The idea is to try to extend the intuitiveness of current 2D Citywall into 3D data space manipulation. The question mark in some action columns denotes that the gesture is currently unbound, while *time* associated with hold means that the binding kicks in after a predefined time interval.

gesture	fingers	hands	action 2D	action 3D
drag	1-5	1	move/pan	spin
+ flick	1-5	1	+ momentum	+ momentum
+ hold	2-10	2	?	tilt
+ hold (time)	1-5	1	?	move
circulate	2-10	2	rotate	spin (counter)clockwise
stretch / pinch	2-10	2	resize	zoom / resize
flick	1-5	1	?	?
wind / swirl [*1]	1-2	1	zoom z in/out	zoom (?)
tap [*2]	1-2	1	open/close, play/stop	open/close
+ double tap	1-2	1	?	?
hold	1-5	1	grab moving object	grab moving object

Table 1: Recognised input gestures as 2D and 3D

For the output language we look to the work of Foley et al (Foley, 1974, 1982) where the linguistic interaction model describes also the graphical output using a language paradigm Foley claims the lexical level as the individual bits and simple graphical drawing primitives, such as lines. The words of the output language are defined as collections of bits (bitmaps) and shapes (rectangles, circles, fonts etc.). The syntactic level describes the layout of the screen. The semantic level describes the temporal structure of the screen. All output elements have attributes that define their appearance (Terrenghi, 2008).

Citywall 2 has bitmaps (photos), 2D and 3D shapes (vector graphics, text), documents (text and HTML) and time-based media (video, audio). The elements can form trees, graphs and sequences (Neilsen, 1992). For example we may use a kite tale to enable representing and enabling a threaded conversation.

Foley, J.D. and Wallace, V.L. *The Art of Natural Graphic Man-Machine Conversation*. In Proc. IEEE 62, 4 (1974), 462–471.

Foley, J.D. and Van Dam, A. *The Art of Natural Graphic Man-Machine Conversation.* Fundamentals of interactive computer graphics. Addison-Wesley (1982).

Nielsen, J. *A Layered Interaction Analysis of Direct Manipulation*, (1992). http://www.useit.com/papers/direct_manipulation.html

Terrenghi, L. *A Taxonomy for Exploring the Design Space of User-Display-Display Interactions.* In PPD'08 workshop proceedings (2008)*, Naples.

Smith, G.M. and Schraefel, M.C. *The radial scroll tool: scrolling support for stylus- or touch-based document navigation*. In Proc UIST '04*, ACM Press (2004), New York..

5.7.4　　Testing and public demonstration

The technology is used in the environmental awareness showcase WP7 and it was tested in public in the European City of Sciences exhibition in Paris (10/2008) with WP6 Urban Renewal. There we showed our demonstration of Multi-Touch Display/CityWall with multiple timelines and content, adding Flickr images from Helsinki since May 2007, images of Paris and Grand Palais, videos of other state of the art multitouch systems, images from Participants in MRTent, a pin board of SMS, MMS, and emails sent to CityWall, as well as a world of help animations. We made video footage of 3 days interaction at the screen & observation of participants in-situ & presence, flow and IMI questionnaires. After ECS we are in post-production, setting up new CityWall at HIIT as a demonstrator to our visitors and passing public, improving and updating the Lasipalatsi version and getting ready press releases etc.

Citywall still operates as a permanent installation in downtown Lasipalatsi, Helsinki and we opened the new 3D version there 8th October, with press and outputting a YouTube video that grabbed more than ¼ million visits within its first two weeks.

5.7.5　　Evaluation

Evaluation of the data relating to redesigned CityWall use in Lasipalatsi, Finland and European City of Sciences, Paris, is still to be conducted and is planned for the coming year.

5.7.6 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 finginers 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 D7.3.

5.8   Audio/Video Streaming

Based on the audio and video streaming work done as part of WP5, in WP4 we are working on the integration of this work in the Device Abstraction Layer (DevAL). Based on an initial review of requirements for DevAL, we quickly discovered that without a working implementation of audio and video streaming according to the work planned in WP5, development of DevAL extensions would not be possible. As such, according to the 18 months plan, we decided to first complete the work on audio and video streaming before beginning work on DevAL. According to our present schedule, work on the WP5 parts of audio and video streaming was completed in late December 2008, and work on DeVAL will begin in February 2009.

5.8.1   Specification

Hardware and OS	Windows XP
Software	LIVE555 Streaming Media Microsoft DirectShow C++
Core Features	Video and audio streaming to local files and remote clients. The standardized Real-Time Streaming Protocol RTP/RTSP is used allowing common media player reception of audio and video streams
Status	stable prototype
Intended users	Any number of users
Showcases	WP8
Relevance beyond project	Any mixed reality or ubiquitous project based on distributed input/output processing

6   Dissemination

Wagner, D., Reitmayr, G., Mulloni, A., Drummond, T. and Schmalstieg, D. *Pose Tracking from Natural Features on Mobile Phones*, In Proc. IEEE ISMAR'08, 2008, Cambridge, UK. Best Paper Award at ISMAR'08.

Weiland, C., Braun, A., and Heiden, W. *Colorimetric and photometric compensation for see-through displays*. ACM SIGGRAPH 2008 Posters (Los Angeles, California, August 11 - 15, 2008). SIGGRAPH '08. ACM, New York, NY

Morrison, A., Jacucci, G, Peltonen, P., Juustila, A., & Reitmayr, G. *Using locative games to evaluate hybrid technology,* British HCI workshop: Liverpool, September 1-5, 2008.

Maquil V, Sareika M, Schmalstieg D., Wagner I. (2009) *MR Tent: A Place for Co-Constructing Mixed Realities in Urban Planning*. GI 2009 (paper submitted).

Wagner I., Basile M., Ehrenstrasser L., Maquil V., Terrin J., Wagner M. (2009) *Supporting the Formation of Communities of Practice: Urban Planning in the MR-Tent*. In: C&T 2009 (paper submitted).

Broll, W., Lindt, I., Herbst, I., Ohlenburg, J., Braun, A., and Wetzel, R. 2008. *Toward Next-Gen Mobile AR Games.* IEEE Comput. Graph. Appl. 28, 4 (Jul. 2008), 40-48. DOI= http://dx.doi.org/10.1109/MCG.2008.85

Broll, W., Herling, J., and Blum, L.: *Interactive Bits: Prototyping of Mixed Reality Applications and Interaction Techniques through Visual Programming*, in Proc. of the 3rd IEEE International Symposium on 3D User Interfaces 2008 (IEEE 3DUI 2008), Reno, Nev., USA,

March 8-9, 2008, IEEE Computer Society, Piscataway, NJ, USA, 109-115. DOI=http://dx.doi.org/10.1109/3DUI.2008.4476600

Ohlenburg, J., Broll, W. and, Lindt, I. *Orchestration and Direction of Mobile MR Games*, in Proc. of the ACM Computer Human Interaction 2008 (CHI 2008) Workshop on Urban Mixed Realities - Technologies, Theories and Frontiers (Florence, Italy, April 5 – 11, 2008).

Ohlenburg, J., Broll, W., and Braun, A.-K., *Morgan: A Framework for Realizing Interactive Realtime AR and VR Applications,* Latoschik, M. E. et al (eds.), Proceedings of the Workshop on Software Engineering and Architectures for Realtime Interactive Systems (SEARIS) at IEEE Virtual Reality 2008 (VR 2008), (Reno, NV, USA, March 9, 2008), Shaker Verlag, Aachen, Germany. ISBN: 978-3-8322-7029-2, ISSN: 0945-0807, 27 – 30.

Acknowledgements and Further Information