WIKICITY: REAL-TIME LOCATION-SENSITIVE TOOLS FOR THE CITY

Francesco CALABRESE
SENSEable City Laboratory
Massachusetts Institute of Technology
77 Massachusetts Avenue, Cambridge,
MA 02139, U.S.A
Tel: 1-617-2537926
Fax: 1-617-2588081
E-mail: fcalabre@mit.edu

Kristian KLOECKL
SENSEable City Laboratory
Massachusetts Institute of Technology
77 Massachusetts Avenue, Cambridge,
MA 02139, U.S.A
Tel: 1-617-2537926
Fax: 1-617-2588081
E-mail: kloeckl@mit.edu

Carlo RATTI
SENSEable City Laboratory
Massachusetts Institute of Technology
77 Massachusetts Avenue, Cambridge,
MA 02139, U.S.A
Tel: 1-617-2537926
Fax: 1-617-2588081
E-mail: ratti@mit.edu

Abstract: The real-time city is now real! The increasing deployment of sensors and hand-held electronic devices in recent years is allowing a new approach to the study and exploration of the built environment.

The WikiCity project deals with the development of real-time location-sensitive tools for the city. It follows the Real Time Rome project that was developed for the 2006 Venice Biennale of Architecture and which aggregated data from cell phones, buses and taxis in Rome to better understand urban dynamics in real-time.

The WikiCity project is concerned with the real-time mapping of city dynamics. This mapping however is not limited to representing the city but becomes also instantly an instrument for city inhabitants to base their actions and decisions upon in a better informed manner, leading to an overall increased efficiency and sustainability in making use of the city environment.

Keywords: real-time city, location based service, urban dynamics, control system.

1. INTRODUCTION

People moving and acting in a city base their decisions on information that is in most cases not synchronized with the time and place they find themselves in when taking that decision. How often have you arrived at the airport just to find out that your flight has been delayed, been surprised by a traffic jam, found that a product is out of stock or a service operator busy at the moment you needed it.

In the same way, a person acting in a city contributes herself to dynamics of which others are not aware of when making their decisions. Looked upon in this way a city resembles what Deleuze and Guattari describe as a "rhizome" (Deleuze & Guattari, 1977). The rhizome is a philosophical network structure where every part is necessarily connected with every other part of the system. There are no preferential connections because every connection alters the overall network structure. As a

consequence, the rhizome can not be plotted since the plotting action itself is part of the rhizome and thus in the very moment of plotting its structure, the structure changes.

The WikiCity project, in a similar way, is concerned with the real-time mapping of city dynamics. This mapping however is not limited to representing the city but instead becomes instantly an instrument for city inhabitants to base their actions and decisions upon in a better informed manner. In this way the real-time map changes the city context as well as that altered context changes the real-time map accordingly. This with the ultimate aim of leading to an overall increased efficiency and sustainability in making use of the city environment.

In order to identify the functional elements needed to construct such an instrument we chose the real-time control system as an analogy to start with. In the past decades, real time control systems have been developed for, and deployed, in a variety of engineering applications. In so doing, they have dramatically increased the efficiency of systems through energy savings, self-organization/repair, regulation of the dynamics, increased robustness and disturbance tolerance.

Now: *can you have a city that performs as a real time control system?*

Let's examine the four key components of a real time control system:

1. entity to be controlled in an environment characterized by uncertainty;
2. sensors able to acquire information about the entity's state in real time;
3. intelligence capable of evaluating system performance against desired outcomes;
4. physical actuators able to act upon the system to realize the control strategy.

A city certainly fits the definition of point 1. Point 2 does not seem to pose particular problems: today's deployment of a range of remote sensors in urban areas allows for unprecedented data collection and analysis. As an example, the Real Time Rome project[1] used mobile phones and GPS devices to collect the movement patterns of people and transportation systems, and their spatial and social usage of streets and neighbourhoods. Information regarding further aspects are already collected continuously by distinct computing systems that track product and service availability, environmental values, climatic conditions, acoustic values, events,…

What about points 3 and 4? How to actuate the city? Although the city already contains several classes of actuators such as traffic lights and remotely updated street signage, their range of use is currently limited. A much more flexible actuator would be the city's own inhabitants: they represent a distributed actuation system in which each person pursues his individual interest in cooperation and competition with others, with the overall behaviour of the system governed by the interaction between individuals. People can also clearly form part of the overall intelligence of the control system.

Towards the above goal, the WikiCity project can be thought of as adding further, interaction-oriented layers to a real-time map of the city and making location and time-sensitive information accessible to users, allowing them full control on the database, onto which they can upload and download data. In this way, these tools enable people to become distributed intelligent actuators and thus became prime actors themselves in improving the efficiency of urban systems.

---

[1] Real Time Rome is a partnership project between the MIT SENSEable City Laboratory and Telecom Italia that was presented at the Venice Biennale of Architecture, 2006, http://senseable.mit.edu/realtimerome/ (see Calabrese & Ratti, 2006).

By deploying developments of the ‘Web 2.0’ and the ‘Semantic Web’ WikiCity can be a significant leap forward towards a pervasive ‘internet of things’ (ITS, 2005) to support human action and interaction.

2. CONTEXT

WikiCity refers to a number of active threads of research and business in different fields on topics such as:

2.1 Sensing

In today’s cities a multitude of digital devices are distributed among people, moving vehicles, static architecture and products to record, store and transfer data of different kinds. Wired, wireless and mobile communication technologies are turning these devices into effective and interconnected sensors that can reflect different variables in a city’s dynamic such as transportation, communication and social patterns, environmental values, the state of buildings and personal values just to name a few (see Calabrese & Ratti, 2006).

2.2 Interactive Maps

Today’s electronically interactive maps like Google Maps (Google Maps, 2006) combine detailed aerial and satellite images, sophisticated zooming-panning interaction and local search functions to create the most powerful maps to date. These maps are also modifiable by users when combined with geotagged, place-related information.

2.3 Wikipedia

Wikipedia (Wikipedia, 2007) is a multi-lingual, Web-based free content encyclopaedia project. Wikipedia is written collaboratively by volunteers, allowing most articles to be changed by almost anyone with access to the Web site.

There has been controversy over Wikipedia 's reliability and accuracy, because information is sometimes unconfirmed and questionable, lacking proper sources that is necessary for an article to be considered “high quality”. However, Wikipedia has a set of policies identifying types of information appropriate for inclusion. Wikipedia articles do not attempt to determine an objective truth on their subjects, but rather to describe them impartially from different viewpoints.

2.4 Real time information

Several web sites provide real time information about current and incoming events (e.g. RSS) in the world. However, it is quite difficult to have a wide source of real time information related to a specific location.

2.5 Intelligent transportation systems

Intelligent Transportation Systems (ITS) refer to transportation systems which use the new ITC technologies (sensory capabilities, memory, communications, information processing) to address and alleviate transportation congestion problems.

A very powerful example of ITS is the one available for the city of London "Transport for London" (TFL, 2007). It gives real time travel news like: timetables, subway’s disruption information, planned works, etc, both on the web and on mobile devices.

2.6 E-business

Services like eBay give the users the ability to sell/buy products through the Internet from one side to the other of the world.

These services work very well if a delay of some days for the shipment is accepted. There are however several transactions that require the real time constraint and that

are possible only with a direct interaction between humans.

2.7 Semantic Web

The Semantic Web (W3C, 2007) is a project and vision of the World Wide Web Consortium to extend the current Web, so that “information is given well-defined meaning, better enabling computers and people to work in cooperation” (Berners-Lee, Hendler & Lassila, 2001). This is important, as the mix of content on the web and in applications built using web architectures is shifting from exclusively human-oriented content to computer-mediated content. In the Semantic Web, data is defined and linked in a way that enables its use for more effective discovery, automation, integration, and re-use across various applications.

2.8 Web 2.0

Web 2.0 is referred to a new generation of internet services that exhibit new characteristics like:

• “network as platform” — delivering (and allowing users to use) applications entirely through a Web browser (see e.g. Google Docs, 2007);

• users owning the data on the site and exercising control over that data;

• an architecture of participation and democracy that encourages users to add value to the application as they use it (the basic concept of Wiki);

• a rich, interactive, user-friendly interface based on Ajax or similar frameworks;

• some social-networking aspects.

2.9 Service Oriented Architecture

Service Oriented Architecture (SOA) (Barry, 2003) is an emerging paradigm for coordinating and utilizing distributed and heterogeneous services. Within this context, the Web Services technologies are designed to support interoperable, machine-to-machine interaction over a network. The Web Services are platform independent systems which use standard network technologies to consent the interoperability between distributed and heterogeneous services in a transparent and flexible way. An opportune cooperation of web services can be used to manage and process data provided by different sources in a transparent way.

2.10 Location & time-sensitive data

The internet as we now know it works very well to retrieve information on a vast number of topics at anytime from anywhere in the world. This “anytime” and “anywhere”, ironically, is also one of its limitations.

In fact, there are several transactions that are location and time sensitive, some examples might be:

• a person who wants to decide the transport to use from his current position in order to reach a certain destination in the shortest time, taking into account the actual traffic condition and further events;

• a person who wants to be updated about the events that are happening or are going to happen in his present surroundings;

• a person who would like to buy/rent a service/product, in a situation where the real time constraint is important (thinking about taxi rides, car sharing but also specific products needed in that very moment nearest to you).

In these cases, the information that nowadays can be stored on the web cannot allow to process such transactions. The WikiCity project aims to answer such needs, making possible to process location & time sensitive transactions.

3. WIKICITY

The WikiCity project aims at combining the benefits of the previously described projects on the basis of creating a common format for interchange of real-time location-based data and a distributed platform able to collect, manage and provide such data in real time.

In this way the city's most informative real-time map can be created, letting users broadcast their location and have site-specific information pushed on them per request. WikiCity can be divided into a number of manageable channels (layers) like mobility, events, aggregate information, and whatever is most useful and efficient for users to search and access the geospatial content they're looking for.

Instead of starting the implementation of the project by a top-down approach such as the definition of standards we consider a bottom-up approach in terms of a case study that allows for experimenting with the platform. For the development of WikiCity a city will be chosen whose local authority becomes a key partner and active agent in the entire process which then is open to and involves potentially all city inhabitants and businesses in the given metropolitan area.

We aim to acquire data from:

1. telecom operators, such as aggregate mobile phones location data and further users information;
2. public transport (bus, subway, train), such as vehicles' locations, paths and time schedules;
3. companies, which have real-time location information of a number of vehicles (e.g. car fleet management, taxi,…);
4. businesses, which want to provide services/products that are location-time sensitive;
5. local authorities, that can add information about upcoming events, activities or environmental conditions.
6. any private individual, that can upload information on general interest, on events, about requests or offerings.

Important for the launch and successful development of such a project is giving and having access to a large critical mass of users. Think of the "chat" phenomenon with no people to chat with or Wikipedia with no one writing content. The aim of this kind of development is to think big, start small and scale up fast.

4. DESIGN CONCEPT AND SCENARIOS

WikiCity is about envisioning new application scenarios on the basis of a technology potential involved in location and time-sensitive information. These scenarios are rooted within the social context of a city for which we have identified three main element groups involved which are Agents, Environment and Technology features. Subsequently we intersect capacities and requirements of these three element groups, the various agents involved, the specific environmental conditions they find themselves operating in and the potential of new technologies.

1. Agents

Private individuals, associations, local authorities, companies, non-profit organizations.

2. Environment

City architecture, infrastructures, landscape, waterways, climatic conditions.

3. Technology features

Positioning, detecting movement, detecting interaction, evaluating density, visualizing, sensing environment values.

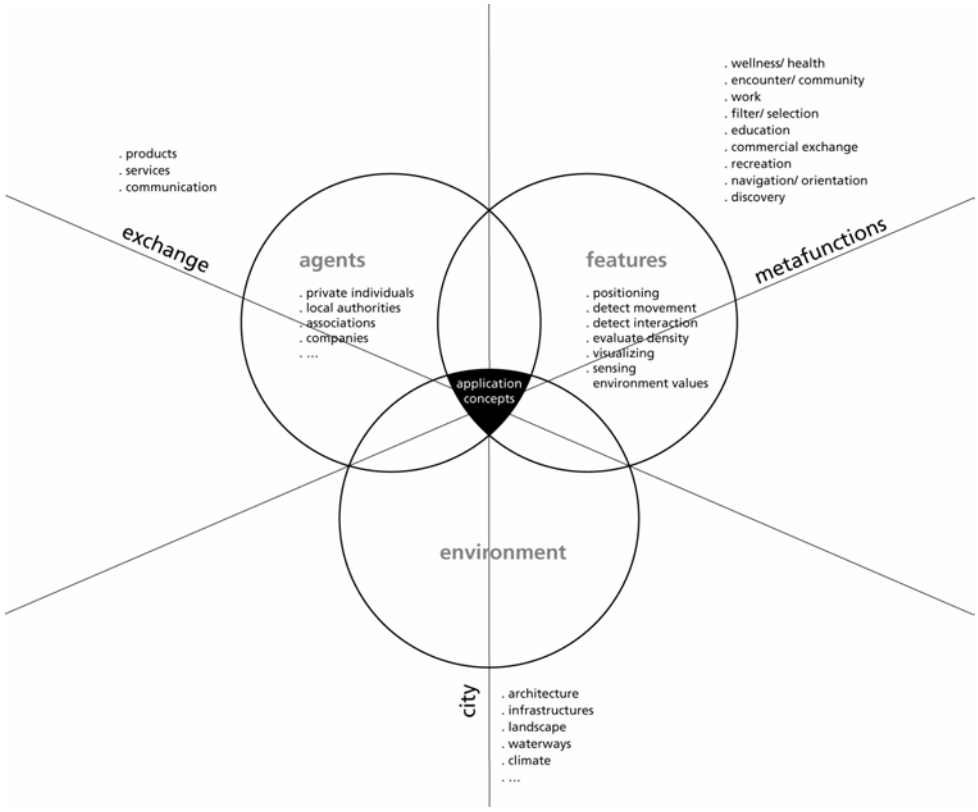


Figure 1. Application scenarios generated by intersection of agents, features and environment aspects

Macro Needs

Considering people living in urban areas we distinguish between four main macro needs that can be addressed in the design of services and products for urban dynamics:

- Safety
- Interaction
- Comfort
- Mobility

Metafunctions

On the basis of these macro needs we identify metafunctions, different for any specific geographic, cultural and technological context, that try to accommodate these needs and which are:

- Wellness/ Health
- Encounter/ Community
- Work
- Filter/ Selection
- Education
- Commercial exchange

- Recreation
- Navigation/ Orientation
- Discovery

By intersecting the metafunctions and the potential of technological features we can identify areas which lead us to new application concepts for the WikiCity project.

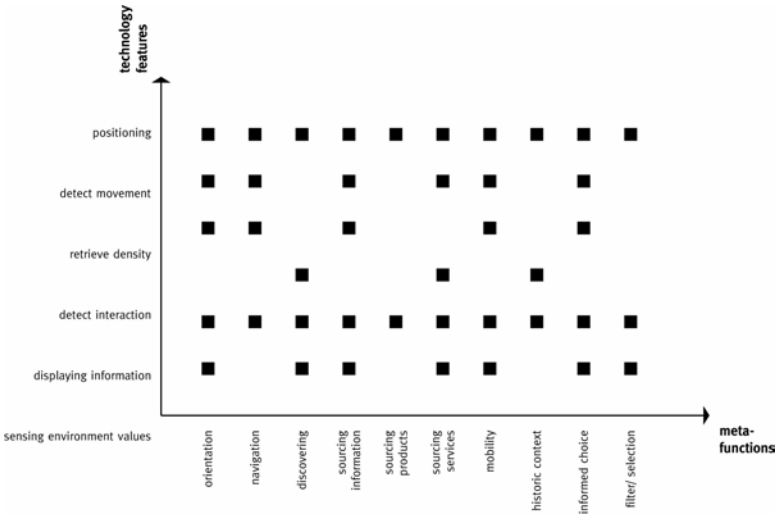


Figure 2. Technology features and metafunctions to generate application fields

Time value

A key characteristic of WikiCity being the circulation of information on a real-time basis, we can identify different "time zones" in which the data can be useful and supportive to different agents and different operations. These determine the way data shall be made accessible.

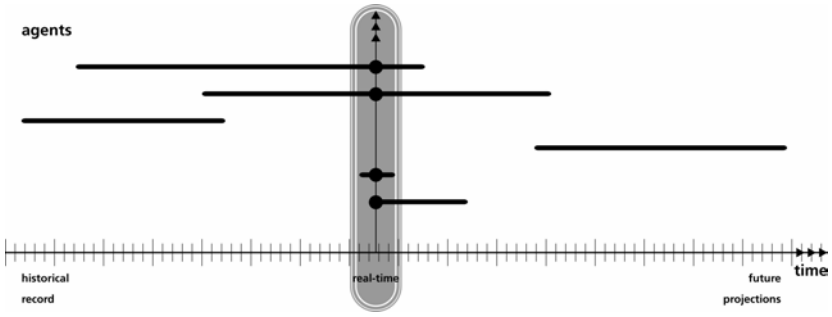
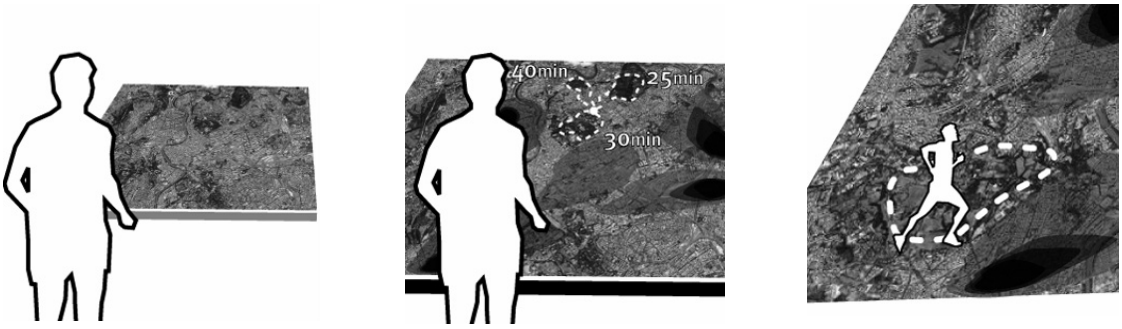


Figure 3. Different time ranges representing value for different agents

Storyboards

As a last step in concept and scenario elaboration the technique of storyboards is used to visualize dynamic situations enabled by the use of the WikiCity project in a modelled real-world situation. The technical potential of location and time sensitive services becomes tangible through the application to a coherent application scenario. The following figure shows an example of such a storyboard:



Wanting to go jogging Tom looks at the WikiCity map to get suggestions on routes considering air quality, traffic calm paths and his physical condition.

The WikiCity map suggests three jogging routes considering air quality, traffic density and Tom's physical condition indicating an approximate time and starting from tom's current position.

Tom chooses his preferred route for the day and sets of for a run. by choosing one route, he can decide whether to record his choice for later and leave suggestions for others.

Figure 4. Jogging path scenario

5. ACCESS MODALITY - INTERFACES

Just as important as the information that can be presented in various circumstances in relation to a city map, the very way the information is made accessible determines the effective outcome and relevant acceptance of the project as such. For this reason WikiCity explores different interface modalities that create connections between the virtual data and the actual physical world where these data is accessed by users. Interfaces to WikiCity can be more closely positioned to the built environment in terms of interior spaces (Desktop PC, Wall projections,...) and or outdoor spaces (info totem, facade display,...); they can be linked to moving vehicles (public transportation, car infotainment centre,...) or they can be closely located to the user himself (Smartphone, PDA, PC Laptop,...).

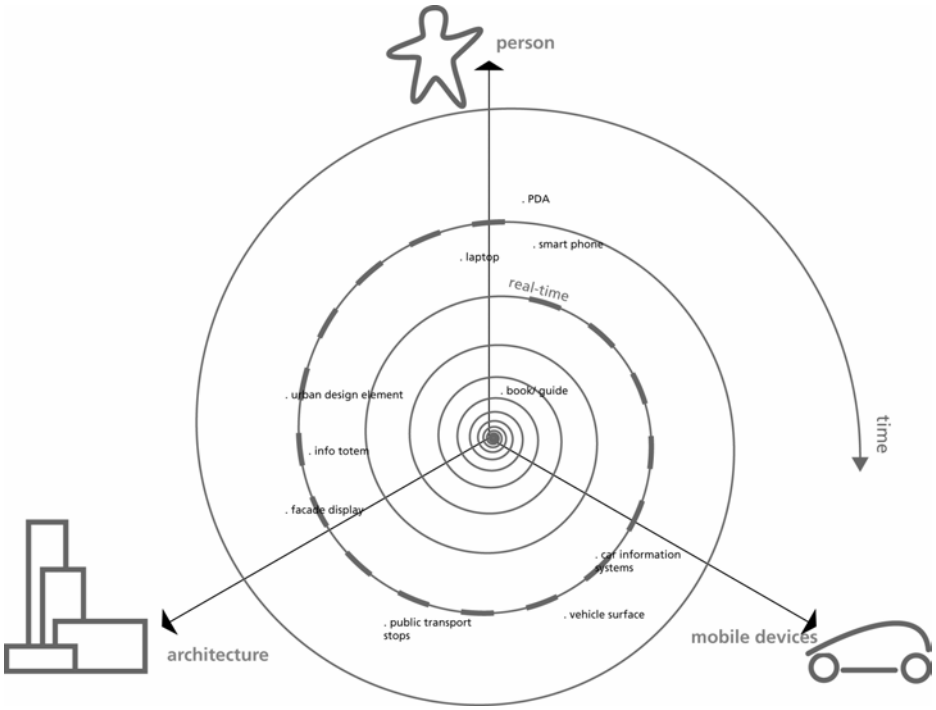


Figure 5. Access modality can be positioned more closely to the user, the built environment or mobile vehicles

The different interface modalities are determined by the application scenario and the involved agents, the type of data and the environmental context within which the scenario is located. A multimodal interface approach shall be followed combining different input and output methodologies. For the actual project implementation however, available technology, project partners and time constrains will determine a step by step approach to integrate the entire range of interface modalities. We shall therefore distinguish two main groups regarding interface design for wiki-city: 2D display interfaces on the one hand and genuinely multimodal interfaces on the other.

5.1 2D Displays

WikiCity shall be accessed through various devices that for now distinguish themselves by consisting in a 2D display as the main means of visualising information from the virtual realm in front of the user. Examples for such devices are smartphones, PDAs and Laptop Computers on the mobile side and desktop computers and static embedded computer-display combinations on the other. These types of devices are widespread in many countries and developing a software solution will be sufficient to gain access to WikiCity information.

While the input method in such devices is rather consistent ranging from a keyboard, a pointing device to a touch-screen, the biggest interface constraint is represented by screen size which can vary from 2" to 17". This factor does influence how information is visualized but to a lesser extend what is visualized, the latter consisting in a series of functional elements to fulfil the project's requirements which are:

Search Field:

Figure 6. 2D interface element: search field

A verbal input field where the user specifies the terms of his search. This search field can be complemented by a limited selection on pre established parameters.

"Local" distance range indicator:

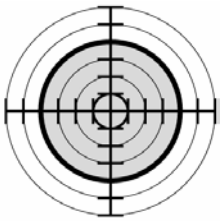


Figure 7. 2D interface element: "local" distance range indicator

Wiki-City, going beyond the web's "anywhere" approach, is based on the user's geographical location. Looking for locally relevant information a user can specify the distance range that she wants to regard as "local".

Time range indicator:

Figure 8. 2D interface element: time range indicator

Similar to the "local" distance range indicator, a time range indicator allows for indicating the time frame one wants to limit it's search results to. Wiki's focus on real-time information can be extended including past or future periods.

Results field:

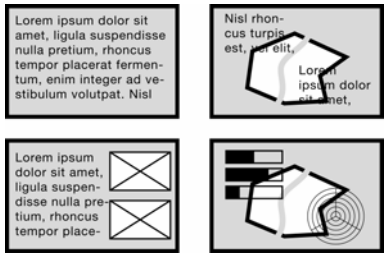


Figure 9. 2D interface element: results field

Following a user specified search in WikiCity within the 2D interface the results will be displayed in a results field. This field does not have predetermined static elements because different combinations of visual information shall be used to represent various information combinations such as:

- Text only
- Text on geographic map
- Text and image
- Diagram on geographic map
- …

5.2 Multimodal interfaces

Looking for connections between the data realm and the user within the urban space, the second focus for WikiCity interfaces shall be put upon built structures. Throughout the urban environment inhabitants are permanently surrounded by structures that can be attributed to urban furniture or built infrastructures, many of which already carry various types of information if also mainly in a static way.

Information data from the virtual realm of WikiCity shall also be accessed through interaction with these structures and three approaches can be clearly distinguished:

1. Embedded access in existing structures
2. Embedded access in existing structural typologies
3. New structural typologies in function of access to WikiCity.

Different from mobile devices in all three of these 3D interfaces, the location is a known constant and it is furthermore to consider that also the information type accessible through immobile 3D interfaces can be limited to a specific mix that results from the interface typology and the environment it is surrounded by.

We are currently looking into different aspects and research done within the range of "tangible user interfaces" (TUI) to further enhance the WikiCity interface considerations.

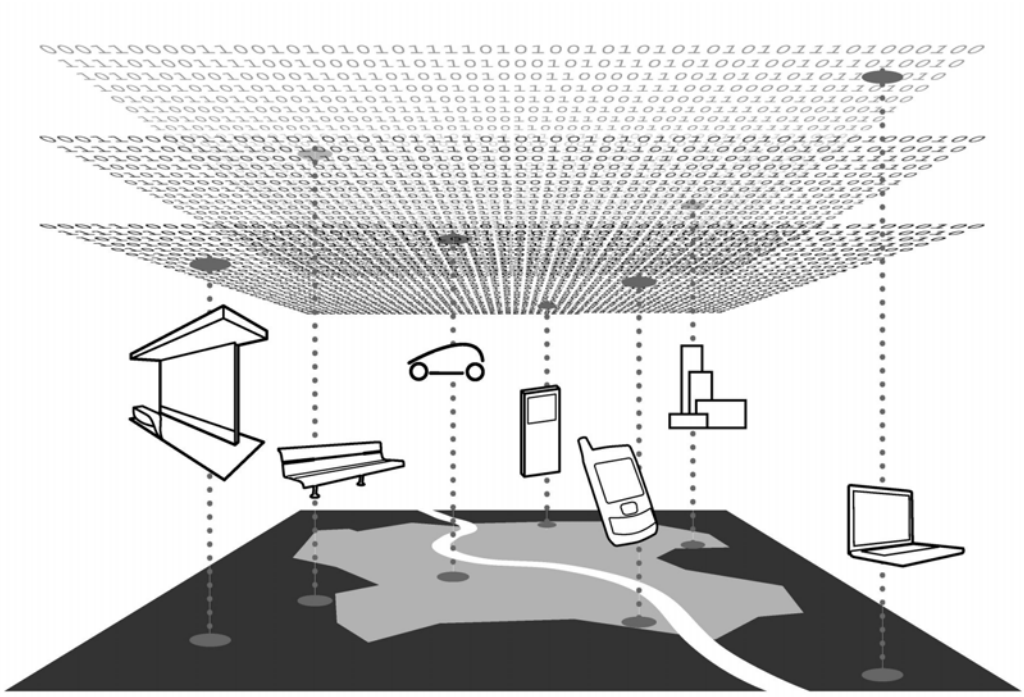


Figure 10. 2D and 3D interfaces as connections between the tangible and the virtual realm of a city.

6. SOFTWARE IMPLEMENTATION

The WikiCity infrastructure is based on standards and on a distributed architecture. The identified architecture is composed of the following components (see Fig. 11):

1. Data authoring;
2. Data acquisition;
3. Data storage infrastructure;
4. Metadata engine;
5. Data Extraction and Processing;
6. User interface.

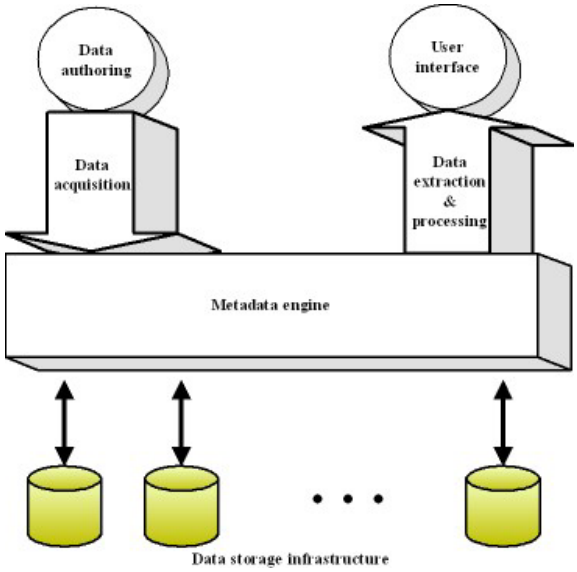


Figure 11. Scheme of the system architecture

6.1 Data Authoring

An ontology describing the application domain has been studied. As consequence, the different categories of information which can be collected by the platform have been formally described. Following this, an XML Schema has been defined to describe the content of each available data. It contains the following components:

- Location (coordinates system, latitude and longitude)
- Time (with fuse)
- Data category
- Data format (single value, matrix, vector, text, image, …)
- Data representation (e.g. measurement unit)
- Data description (semantics of the data)
- Raw Data or link to the data (if the data is not contained into the XML file, e.g. an external image).

The Data Authoring regards a set of tools, scripts and methodologies to translate the raw information provided by the data sources into the defined XML format, described by the XML Schema.

6.2 Data Acquisition

The Web Services technology provides an uniform interface for data providers to send the locational data and managing the real-time constraint imposed by the application.

We have identified three different ways of data uploading, based on the provider's requirements (see Figure 12).

For single users, we have implemented a web application, where the location, time, information (text or other) can be inserted by filling the required fields (see red arrows).

For big providers, we have implemented a java library, which can be embedded into a provider’s application. When new data are available, the application directly calls an appropriate routine which creates the Data Description XML file and sends it to the platform. In this way, the data remains into the provider's server and becomes accessed, if needed, by means on external links (see blue arrow).

We have also implemented a FTP server where big and medium providers can, in an asynchronous manner, upload the information. Such information are processed by a local algorithm which inserts them into the Data Description Database (see green arrows). Observe that the provided data must already comply with the Data Description XML Schema, defined in the Data Authoring section.

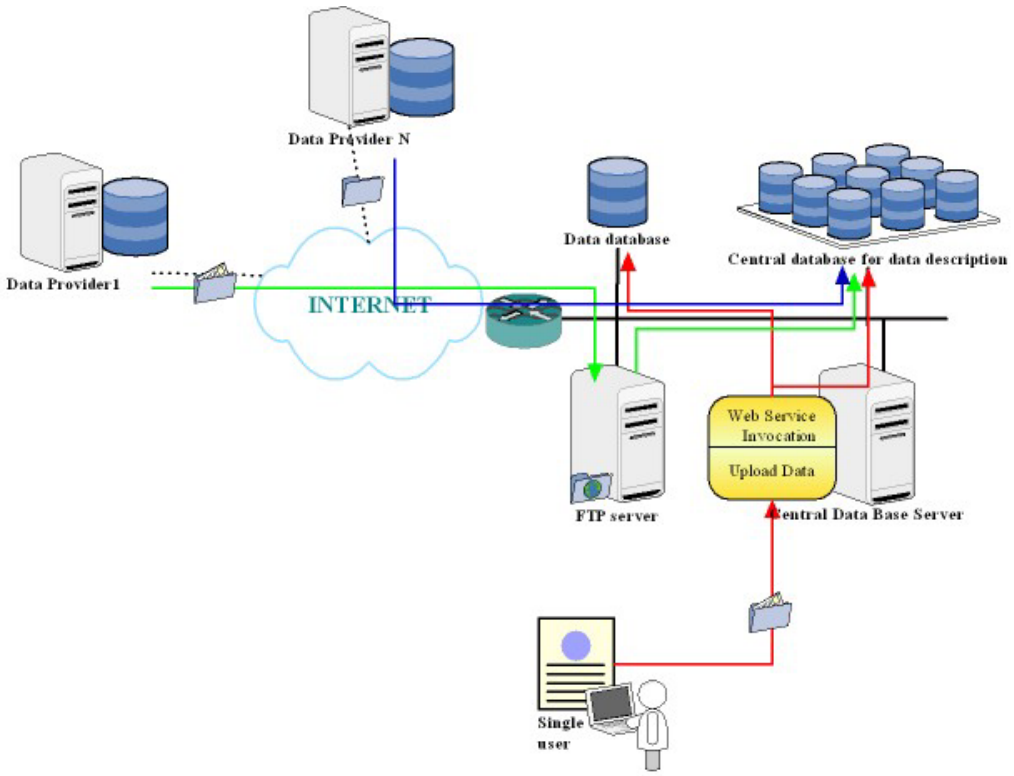


Figure 12. Scheme of the different ways of data uploading

6.3 Data Storage Infrastructure

The application requires effective, scalable storage, management, and navigation of large data sets. The data storage infrastructure has been particularly designed considering the time-location relevance of the data, i.e. it provides an effective way of refreshing the data based on the new provided information.

An Hybrid system has been designed, which combines two different approaches. It is composed of:

• one centralized database where all the data descriptions are stored;

• several databases, located into the internal network and in the service providers' servers, where the data which are referred by the system are stored.

6.4 Metadata Engine

A management system has been developed in order to guarantee the ACID proprieties of the transactions performed using the stored data. It makes use of a Metadata Engine that is able to handle different kinds of data (text, audio, video, etc).

6.5 Data Extraction and Processing

A new type of browsing across data sources, based on location and time constraints, is required to support Data Extraction. A data processing, based on web services composition and orchestration (see BPEL4WS, 2007), is used to this end.

It makes use of a BPEL4WS engine where the business process is created at run-time based on the client's request (Fig. 13). Such process accesses the different databases to download the data relevant to the application. Then, it calls appropriate processing algorithms to merge the data and retrieve the answer to the query.

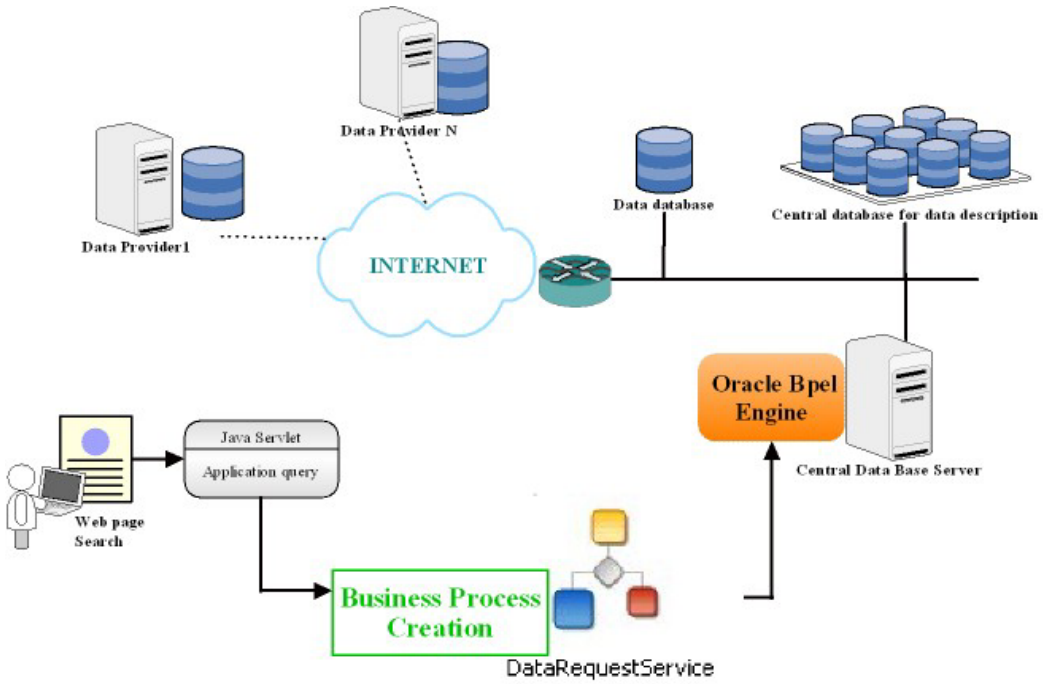


Figure 13. Scheme of the data search

As an example of business process, Figure 14 shows the BPEL orchestration process created to answer the query of the storyboard described in section 4 (Jogging path). Such process is composed of 4 services' invocation that allow to download data about: Traffic, Air Quality, Noise Level, Adequate Running Path. Then a *MergeData* service is used to process such data in order to retrieve the best jogging path, corresponding to the location where all the indications give good results, in terms of traffic, air quality, noise level and adequate paths.

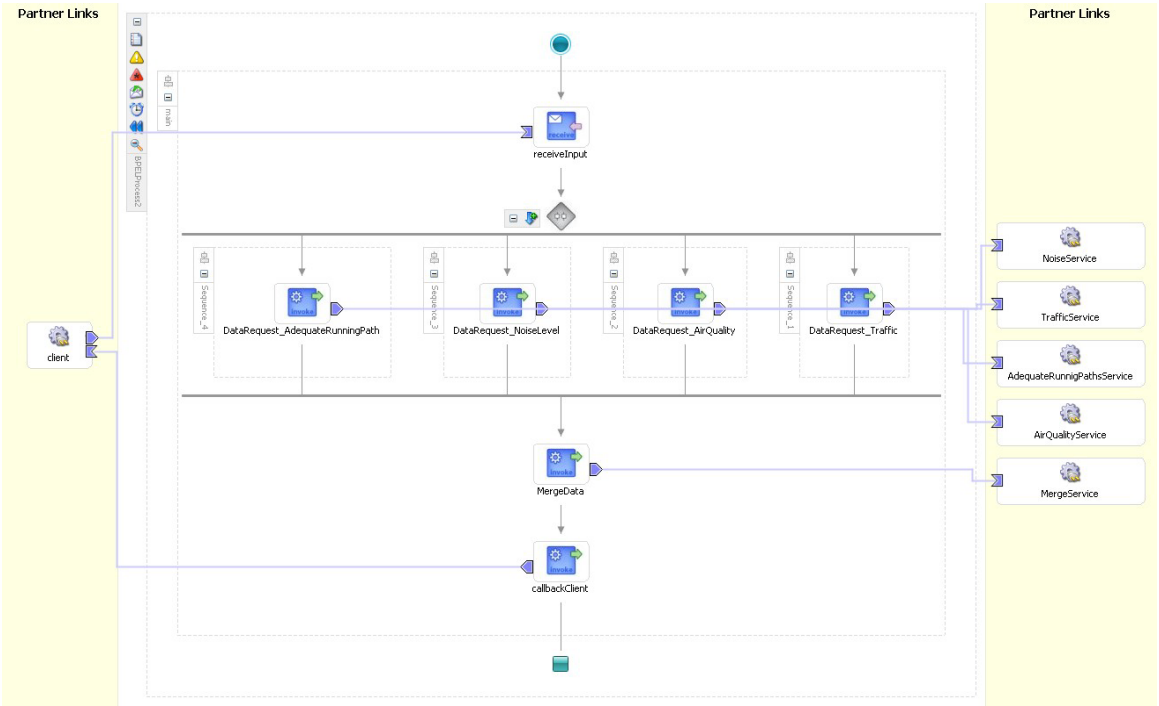


Figure 14. Business process related to the query Jogging path

In order to download the data from the distributed database, the service *DataRequest* is invoked. It is realized by means of another business process (see Figure 15) which uses a Java application to download the Data Description from the centralized database. Consequently, the process knows the location of the external database where the needed data is stored, and calls another java application to get such data.

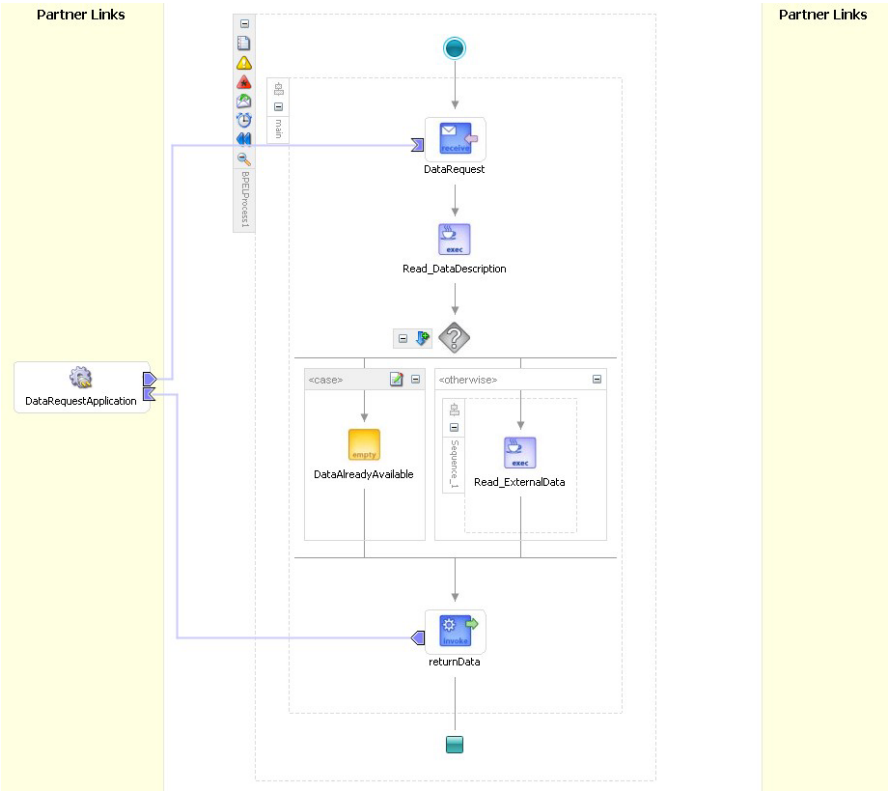


Fig. 15. Business process that Implements the service DataRequest

6.6 User Interface

This category involves the creation of a variety of interactive tools for browsing, searching, and navigating through and among diverse, distributed collections of data. New browsing methods have been developed (e.g. browsing by timeline or distance range) to support the new type of data available. The User Interface has been designed in two ways:

• General: It is based on a city map where different layers can be added. Such layers represent real-time location-based information available in the system. The user views the data like watching the city using a particular lens.

• Personalized: Based on the user location (retrieved in an automatic way by using location technologies or defined by the user) and a specific query, the data extraction tool mines the real-time data base and retrieves the best answer to the query.

7. CONCLUSION

This paper presents work in progress about the WikiCity project.

From a conceptual analysis, the benefits of real-time location-sensitive information to city inhabitants seem fairly clearly indicating how this could contribute to the efficiency of various real-world situations. Critical aspects have emerged however as

to how this new form of information may impact some situations in terms of distributing and diffusing or concentrating attention of users. Will WikiCity lead to more people attempting to be at the same place at the same time or in an increasing number of different places in diverse times. Further analysis of such potential situations will feed back in the design of the way real-time location-sensitive information is communicated and made accessible.

While aiming at the construction of a diffused network structure we have seen that for the initial start-up phase a hybrid system is necessary, which combines the two different approaches of the centralized database and those located within the internal network and in the service providers' servers.

We aim also to use the potentialities of ontologies and distributed services orchestration to tackle the problem of data exchanging, filtering and processing.

Since the implementation of a system such as WikiCity is gradual, regarding interface design we have taken the position of identifying two distinct phases, the first of which being a 2D interface design appropriate for already widely deployed communication devices. The second approach addresses access modality to virtual data in a broader vision taking into account multimodal interface design such as has been attempted by different research groups under the name of "tangible user interfaces".

REFERENCES

Anceschi G., (1992). **Il progetto delle interfacce. Oggetti colloquiali e protesi virtuali**. Domus Academy, Milan.

Barry D. K., (2003). **Web Services and Service-Oriented Architectures: The Savvy Manager's Guide**. San Francisco: Morgan Kaufmann Publishers.

Berners-Lee T., Hendler J., Lassila O., (2001). **The Semantic Web**, Scientific American, May.

BPEL4WS, (2007). Business Process Execution Language for Web Services version 1.1, http://www-128.ibm.com/developerworks/library/specification/ws-bpel/

Calabrese F., Colonna M., Lovisolo P. Parata D., Ratti C., (2007). Real-Time Urban Monitoring Using Cellphones: a Case-Study in Rome, **IEEE Communications Magazine**, submitted.

Calabrese F., Ratti C., (2006). Real Time Rome, **Networks and Communication studies**, vol.20, n.3/4.

Deleuze G., Guattari F., (1977). **Rizoma**. Pratiche Editrice, Parma-Luca.

Google Docs, (2007). maps.google.com, accessed: 12 January 2007.

Google Maps, (2007). maps.google.com, accessed: 12 January 2007.

ITU, (2005). The internet of things. **Report of the International Telecommunication Union**, Geneva.

TFL, (2007). Transport for London, http://www.tfl.gov.uk/tfl/, accessed: 12 January 2007.

W3C, (2007). Semantic Web, http://www.w3.org/2001/sw/, accessed: 12 January 2007.

Wikipedia, (2007). www.wikipedia.org, accessed: 12 January 2007.