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NOTE

Real Time Rome

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Abstract.— In today's world, wireless mobile communications devices are creating new dimensions of interconnectedness between people, places, and urban infrastructure. This ubiquitous connectivity within the environment can be observed and interpreted in real-time through aggregate records collected from communication and transportation networks. The real-time acquisition can regard traces of information and communication networks, movement patterns of people and transportation systems, spatial and social usage of streets and neighbourhoods. This paper reports on the Real Time Rome project, exhibited at the 10th International Architecture Exhibition in Venice, Italy. The Real Time Rome project is the first example of an urban-wide real-time monitoring system that collects and processes data provided by telecommunications networks and transportation systems in order to understand patterns of daily life in Rome. Observing the real-time city becomes a means to understanding the present and anticipating the future urban environment[3].

Keywords.—Urban technology, Real-time city, Location-based services, Intelligent transportation systems, GSM, GPS, Real time control systems.

Location-based data are becoming increasingly available and their application is currently a hot topic in the mobile devices industry. They are generally referred to as Location-Based Services (LBS) – value-added services for individuals in the form of new utilities embedded in their personal devices (see for instance http://www.lbszone.com/ and Blonz, McCarthy, 1998). Revenues from mobile location-based services in the European market are expected to grow by 34 % annually to reach € 622 million in 2010, according to a new report from the research firm Berg Insight (2006).

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The driving force behind the development of LBS services was the need for rescue personnel (and operators) to determine the position of emergency calls. This need was expressed by the US Federal Communications Commission with the initiative called 'Enhanced 911' and by the European Union with the European Universal Service Directive 2002/22/EC2. Since then, a number of new commercial services based on location have been developed, principally focused on the individual user as customer.

Recently a new kind of LBS has been developed to support Intelligent Transportation Systems (ITS). The idea is to monitor the location of a certain number of vehicles (seen as probes) to retrieve information such as travel time estimation, congestion and incident information, traffic census, etc.

However, aggregated location-based data have rarely been used to describe urban systems as a whole. As mobile digital devices (both GPS receivers or cell phones) can be considered as position and displacement sensors, distributed in a capillary manner, the aggregate elaboration of such sensor data allows the estimation of people flows and then gives further views of the city, which dynamically change. The works developed in Amsterdam (Polak, 2002), Tallinn (Ahas, Ülar, 2005), Milan (Ratti, Pulselli *et al.,* 2005) and Graz (Ratti, Sevtsuk *et al.*, 2005) are some examples in this field. The Amsterdam Real Time project (Polak, 2002) aimed to construct a dynamic map of Amsterdam, Netherlands, based solely on the movement of a selected number of people carrying GPS receivers and being tracked in real time. A research group in Tallinn, Estonia (Ahas, Ülar, 2005) made a study of human activity using aggregated mobile phone location data of about a hundred people carrying cell phones and being tracked. The Mobile Landscapes project (Ratti, Pulselli *et al.*, 2005) showed a geographical mapping of cell phone usage in the metropolitan area of Milan, Italy, at different times of the day. A real time cell phones monitoring system was developed for the "Graz in Real Time" project (Ratti, Sevtsuk *et al.*, 2005), based on cell phone traffic intensity, traffic migration (handovers) and traces of registered users as they moved through the city.

This paper describes the system developed for the Real Time Rome project, MIT SENSEable City Laboratory's contribution to the 10th International Architecture Exhibition in Venice, Italy, dedicated to Cities, Architecture and Society. The Real Time Rome project is the first example of an urban-wide real-time monitoring system that collects and processes data provided by telecommunications networks and transportation systems. More precisely, it uses locational data from *i)* mobile phone subscribers of the leading Italian cell phone provider Telecom Italia, *ii)* public buses ran by the local transport company Atac and *iii)* taxis run by the cooperative Samarcanda to understand patterns of daily life in Rome. We interpolated the aggregate mobility of people according to their mobile phone usage and visualized it synchronously with the flux of public transit, pedestrians, and vehicular traffic. By overlaying mobility information on geographic references of Rome we revealed the relationships between fixed and fluid urban elements. These real-time maps help us understand how neighborhoods are used in the course of a day, how the distribution of buses and taxis correlates with densities of people, and how different social groups, such as tourists and residents, inhabit the city.

SYSTEM ARCHITECTURE

How is the transfer of large amounts of data organised in real time?

Three servers were set up by Telecom Italia, Atac and Samarcanda to provide locational data (see Fig. 1). A server with a MySQL database was set up and run at the MIT SENSEable City Lab, both with some Java applications which collected the data from the external servers, pre-processed them providing the results to an internal SFTP server. Six computers at the Venice Biennale exhibit continuously accessed the SENSEable City Lab FTP server and ran algorithms to visualize the different dynamic maps of the city in real-time, using Google maps as background. Furthermore, three computers connected to three audio streaming sources (coming from three audio sensors installed in Rome) played locational traffic noise in time-synchronization with the visual software. The overall time elapsed from data acquisition to processed information visualization in Venice was designed to be less then one minute.

LOCATIONAL DATA

The developed system used seven different kinds of locational data:
a) location of buses;

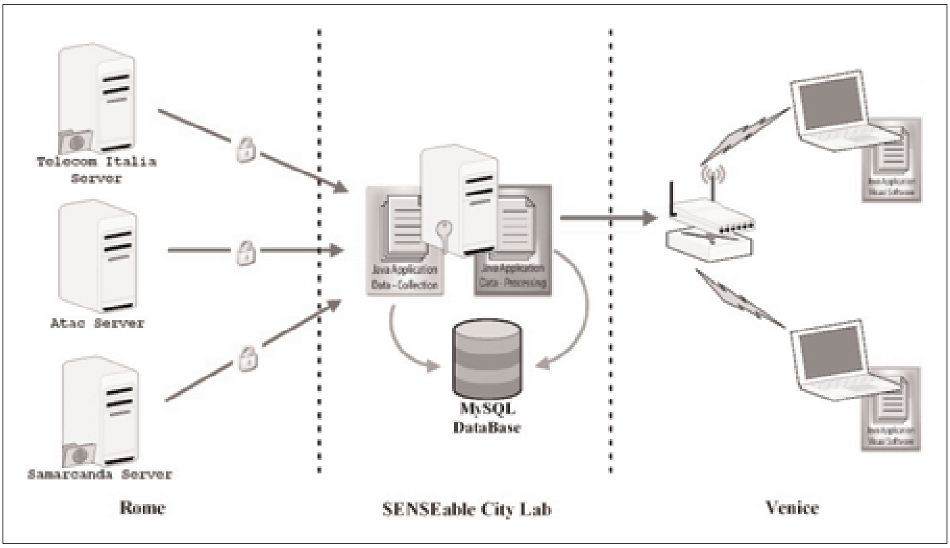

Figure 1. Schematic of the data collection, transfer and processing

b) location of taxis;
c) traffic noise;
d) amount of telecommunication traffic;
e) density of tourists (foreigners);
f) density of pedestrians;
g) density and speed of vehicles.

The data *a)* and *b)* were provided by GPS devices located in buses and taxis run by Atac and Samarcanda. The data *c)* was provided by a wireless sensor network installed in Rome.

The amount of telecommunication traffic *d)* was collected using a Telecom Italia server, that acquired the telecommunication traffic intensity[4] of all the GSM cells located in the urban area of Rome (covering about 47 Km^2). This data was collected, aggregated every 15 minutes and sent to the SENSEable Server at MIT.

The remaining data (*e, f* and *g*) was obtained processing the location data of mobile phone calling users, obtained using a new wireless location technique. Telecom Italia designed an innovative location platform "Lochness" based on acquisition systems connected to the Abis[5] interfaces of several GSM Base Station Controllers (BSC) in Rome. By means of them we acquired the following information: Cell location (Cell ID), Angle of Arrival (AOA), Timing Advance (TA), and Received Signal Strength (RSS) of mobile phones engaged in calls in the area of Rome covered by the related Base Transceiver Stations (BTS) (the area covered was approximately 100 Km^2 in the north-east of the city). Using information about the base station locations, irradiation diagrams and propagation models, ad-hoc developed algorithms allowed the position of each calling user to be estimated.

The location data was then aggregated and anonymized[6] to create several matrices, whose elements corresponded to 250 by 250 meter squares of the covered area of Rome. Each matrix was related to a different category:

The *density of tourists* was obtained selecting only the location data of users supposed to be foreigners (by analyzing the first three digits of the IMSI[7] of the localized users).

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4. The telecommunication traffic intensity is usually measured in Erlang. One erlang is one person-hour, or the equivalent of one caller speaking for one hour on one phone or two callers speaking for 30 minutes each.

5. The Abis interface is an interface, within the GSM architecture, between the BTS (Base Transceiver Station) and BSC (Base Station Controller).

6. In the EU, the privacy issue is regulated by a 2002 Directive by the European Parliament and Council, that allows location data to be processed by Telecom operators provided that they are made anonymous (or with the consent of the users) and they are collected for a provision of a value-added service.

7. An International Mobile Subscriber Identity, or IMSI, is a unique number that is associated with all GSM and Universal Mobile Telecommunications System (UMTS) network mobile phone users. An IMSI is usually fifteen digits long. The first three digits are the country code (mobile country code), The remaining digits are the Mobile Network Code (MNC) and the unique subscriber number (MSIN) within the network's customer base.

The *density of pedestrians* was obtained selecting only the location data of users supposed to be moving at a low speed. To this end, an ad-hoc developed algorithm was used to estimate, for each user, the trajectory followed and the speed. Based on this, a sophisticated algorithm was used to select data coming only from pedestrians (in particular, the algorithm was developed in order to discriminate between a very slow mobile phone located in the pocket of a pedestrian from one of a driver stuck in traffic).

The *density of vehicles* was obtained selecting only the location data of users supposed to be in vehicles. To this end, an algorithm similar to the one presented above was used. Moreover, it allowed the vehicles' speed and direction to be estimated, which were aggregated in order to create four different matrices related to the average speeds in the four quadrants NE, SE, SW, NW of each pixel.

PROCESSING AND VISUAL SOFTWARE

In the following subsections, a detailed description of the processing and visual software is given, starting form the questions they address.

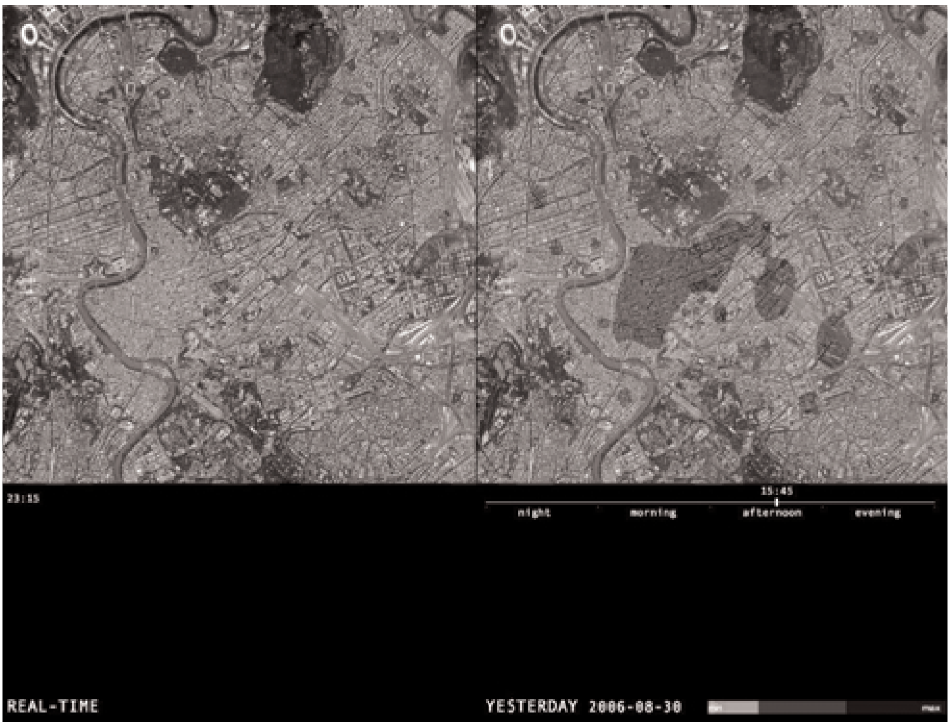

Figure 2. Pulse: What are the patterns of use in Rome?

A. Pulse: Where in Rome are people converging over the course of a day? (see Fig. 2)

This software visualized the intensity of mobile phone calls in Rome at the present moment and compared it to the previous day's data.

It is based on a geographic interpolation of the telecommunication traffic intensity data. To this end, the Rome urban area was divided in 40x40m pixels and an exponential distribution function was used, to assign a traffic intensity value at each pixel.

The software showed the real time data (updated every 15 minutes) on the left side, and a loop of the previous day's data, constituted by 96 different images, on the right side.

B. Gatherings: How do people occupy and move through certain areas of the city during special events? (see Fig. 3)

This software showed the pre-recorded intensity of mobile phone usage during important events in Rome:

• viewing the World Cup final match between Italy and France on July 9, 2006 and celebrating the arrival in Rome of the winning Italy national team on July 10 (Fig. 3.a);

• Madonna's concert in Rome on August 6, 2006 (Fig. 3.b).

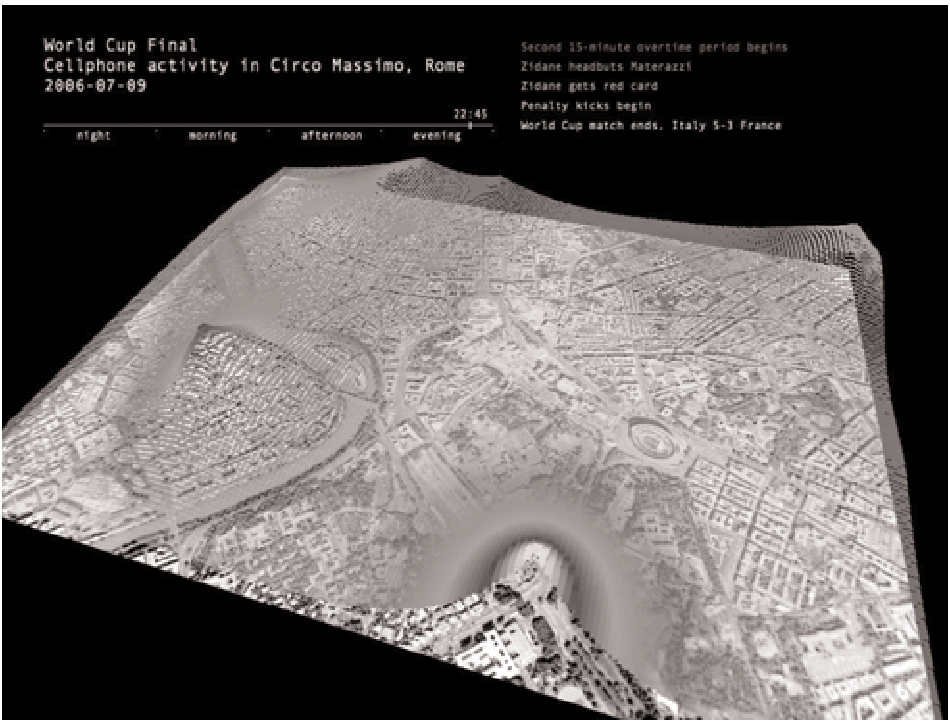

Figure 3a. Gatherings: What does Rome look like during special events? World Cup final match

The software was realized by concatenating 3D visualizations of the traffic intensity in specific areas of Rome and at different times of the selected days.

C. Icons: Which landmarks in Rome attract more people? (see Fig. 4)

This software showed the density of people using mobile phones at different historic attractions in Rome. To this end, a weighted mean was calculated for each attraction, based on the traffic intensity associated with the pixels located corresponding to the attraction site.

A bar on the top of each attraction showed the relative traffic intensity, while at the bottom of the screen a week-long data comparison between the most popular site and the least popular site was shown. Every 15 minutes, when the new data was available, both the top and the bottom of the screen were updated based on the new ranking.

D. Visitors: Where are the concentrations of foreigners in Rome? (see Fig. 5)

This 3-D software highlighted a 24 hour loop of the locations around the Stazione Termini neighborhood of Rome where foreigners were speaking on mobile phones. An

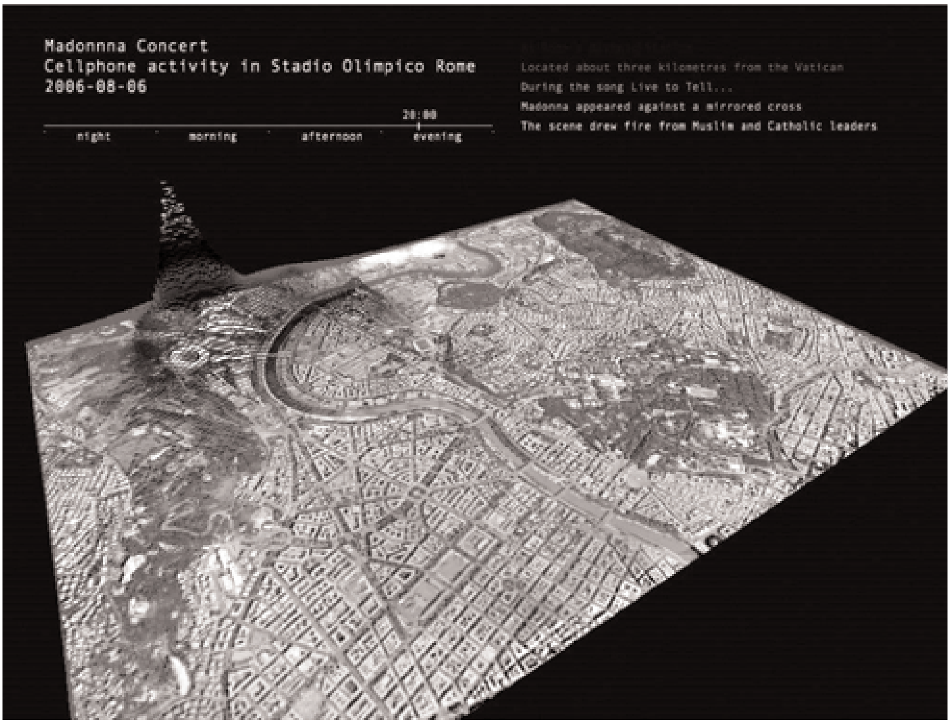

Figure 3b. Gatherings: What does Rome look like during special events? Madonna's concert

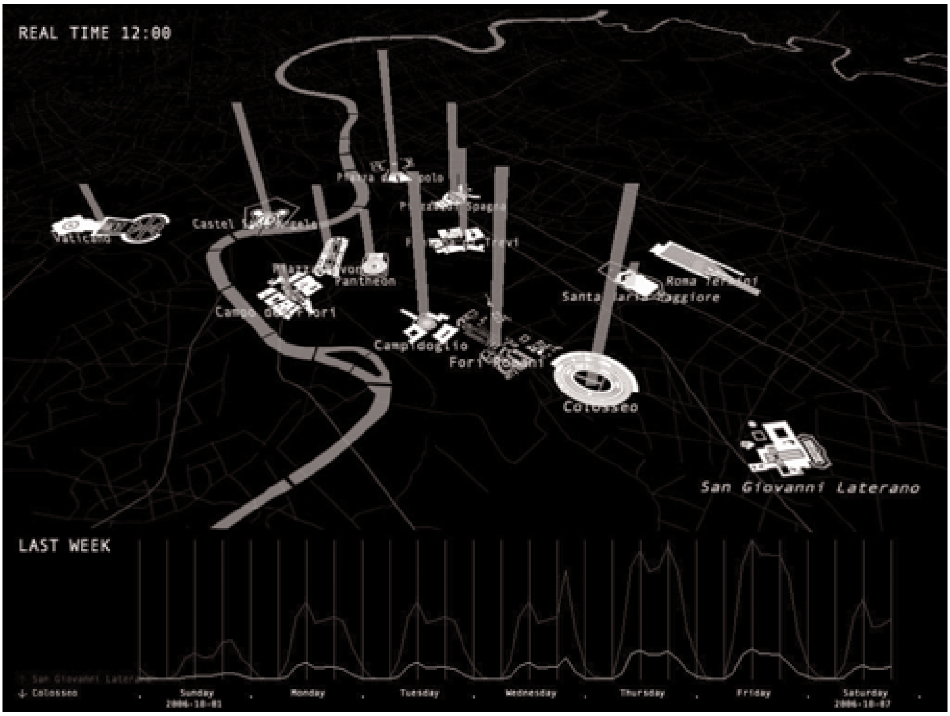

Figure 4. Icons: Which landmarks in Rome attract more people?

algorithm created a 48-length data queue where, with a sampling rate of 1/30 minutes, the locational data of the newest foreigner was added (deleting the oldest one).

E. Connectivity: Is public transportation where the people are? How do the movement patterns of buses and taxis and pedestrians overlap in the Stazione Termini neighborhood of Rome? (see Fig. 6)

This software showed the changing positions of Atac buses and Samarcanda taxis indicated by yellow points, and the relative densities of mobile phone users, represented by the red areas. An algorithm was used to acquire and update the location of buses and taxis in real time. It also estimated buses and taxis paths based on the previous locations, drawing a yellow tail on the map. If the tail was long, this meant that a bus or a taxi was moving fast.

The algorithm acquired the pedestrian locational data every 5 minutes, showing a red layer on the top of the map (areas colored by a deeper red had a higher density of pedestrians).

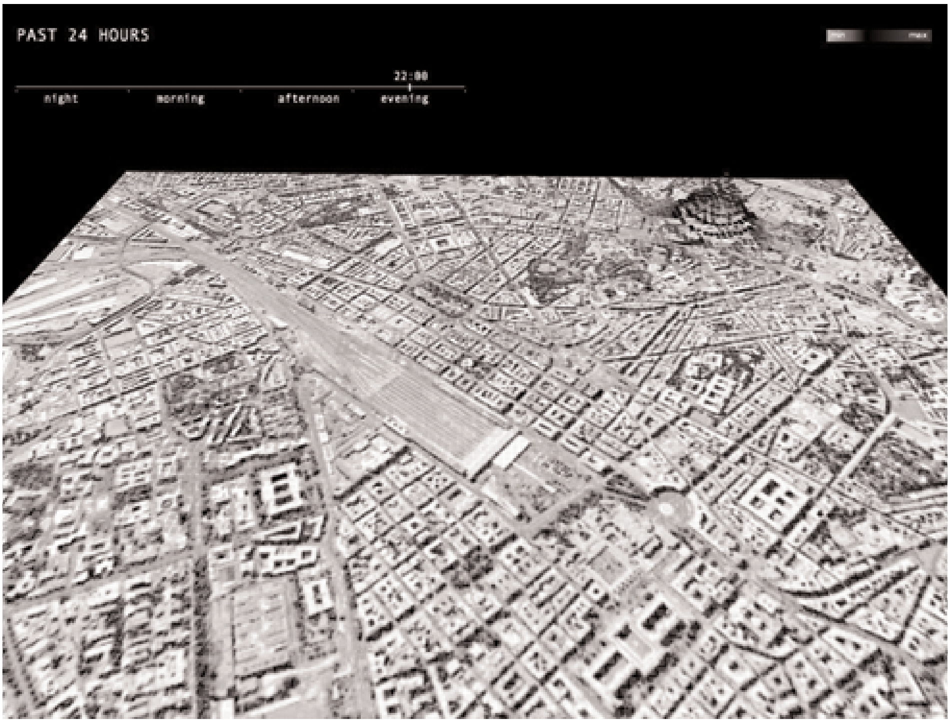

Figure 5. Visitors: Where are foreigners congregating?

F. Flow: Where is traffic moving? (see Fig. 7)

This software visualized the locational data of mobile phone callers traveling in vehicles. It focused on the area around the Stazione Termini and the Grande Raccordo Anulare (Rome's ring road). The software created a layer on the top of the map, showing 250x250 meter pixels whose colors were related to vehicle speeds. Red indicated areas where traffic was moving slowly, green showed areas where vehicles were moving quickly.

If the average speed associated with the pixel was higher that 40km/h, the software also showed an arrow in the center of the pixel, whose direction was the dominant direction of travel and magnitude was proportional to the related speed.

G. Traffic noise

A wireless sensor network was developed and implemented to acquire real-time traffic noise from different spots in Rome to be played at the Venice Biennale exhibition.

Three Via EPIA boards were located in three different locations in Rome to acquire real time traffic noise through capacitor microphones. An audio streaming technology, based on MP3 audio content encoding and HTTP/TCP transport

Figure 6. Connectivity: Is public transportation where the people are?

protocol (Nullsoft, 2006), was used to send such noises to Venice. Then three computers equipped with audio spotlights (Holosonics Research Labs, 2006) were used to play the real-time audio contents in synchronization with the visual software.

CONCLUSION

In this paper a detailed description of the Real Time Rome project, developed for the 10th International Architecture Exhibition in Venice has been presented. The project showed how an extensive monitoring of a big city can happen in real time, helping us understand the ways people and urban systems use city space.

For example, the software *Connectivity* indicated how the locations of public transportation and pedestrians evolved simultaneously. For a transit authority, such information can help them design more responsive and accurate transit routes to serve passengers. For pedestrians, such information can provide them with a better set of options to choose their mode of transportation. The software Visitors had the capacity to capture the location of social gatherings. By showing the concentration of visitors at important landmarks in Rome, we saw which destinations were more popular during different times of day or different days of the week. Will standard

Figure 7. Flow: Where is traffic moving?

queuing theory apply so that tourists try to visit less crowded locations? Or will there be a progressively skewed traffic pattern, with tourists being drawn to the desirability of a venue, thereby increasing the flow of visitors to already crowded locations?

Such analysis, which could not have been addressed previous to the widespread use of digital communications technologies, has now become feasible using tools like the ones presented in this paper. In the long run, individuals will be able to use these tools to make more informed decisions about how they move about their environment. Thus it will become possible to reduce the inefficiencies of present day urban systems and hopefully open the way to a more sustainable urban future.

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