# Monitoring human mobility in urban systems: a new technique based on cell-phone activity.

*Riccardo M. PULSELLI, Pietro ROMANO, Stefano MAGAUDDA, Enzo TIEZZI*

(Dr. Riccardo PULSELLI, University of Siena, Via della Diana 2A, pulselli@unisi.it)
(Arch. Pietro ROMANO, University of Siena, Via della Diana 2A, pietro.romano@unisi.it)
(Arch. Stefano MAGAUDDA, University of Rome III, smagaudda@uniroma3.it)
(Prof. Enzo TIEZZI, University of Siena, Via della Diana 2A, tiezzienzo@unisi.it)

## 1 ABSTRACT

This paper presents a new technique for monitoring human mobility in a territorial system based on cell-phone activity. Considering that cells are the areas covered by the signal transmitted by an antenna that records the number of users connected while they make a call, mobile-telephone traffic data was monitored for each cell in a wide region. Based on this data regarding the position and intensity of mobile phone use, it is possible to monitor daily variations and how these variations change over time. Based on the statistics, we are in a position to presume that the telephone traffic in a certain region is indicative of the effective population density and its variation in 24 hours.

While exploiting new techniques developed for mobile phone systems, this study presents a spatial analysis of social dynamics in urban areas. Mobile phone activity data was represented in a series of maps in order to visualize patterns of geo-demography in a given territory and to provide a kind of dynamic population census in an urban system. Variations in telephone traffic, monitored in time and space, portray city life based on people's actual movements and how they use space and infrastructures. Different ways of using urban space can be monitored and measured over time. Two case studies were developed in the metropolitan area of Pescara (central Italy) and a coastal area on the Adriatic sea and in the metropolitan area of Milan. This research project was carried out in collaboration with an Italian telecommunications company.

## 2 INTRODUCTION

Cities are among the main responsibles for the present environmental problems: climate change, global warming and depletion of resources. "We [European cities and towns] understand that our present urban lifestyle, in particular our patterns of division of labour and functions, land-use, transport, industrial production, agriculture, consumption, and leisure activities, and hence our standard of living, make us essentially responsible for many environmental problems human kind is facing. This is particularly relevant as 80 percent of Europe's population live in urban areas. […] Therefore, cities and towns are key players in the process of changing lifestyles, production, consumption and spatial patterns" (AALBORG CHARTER 1994).

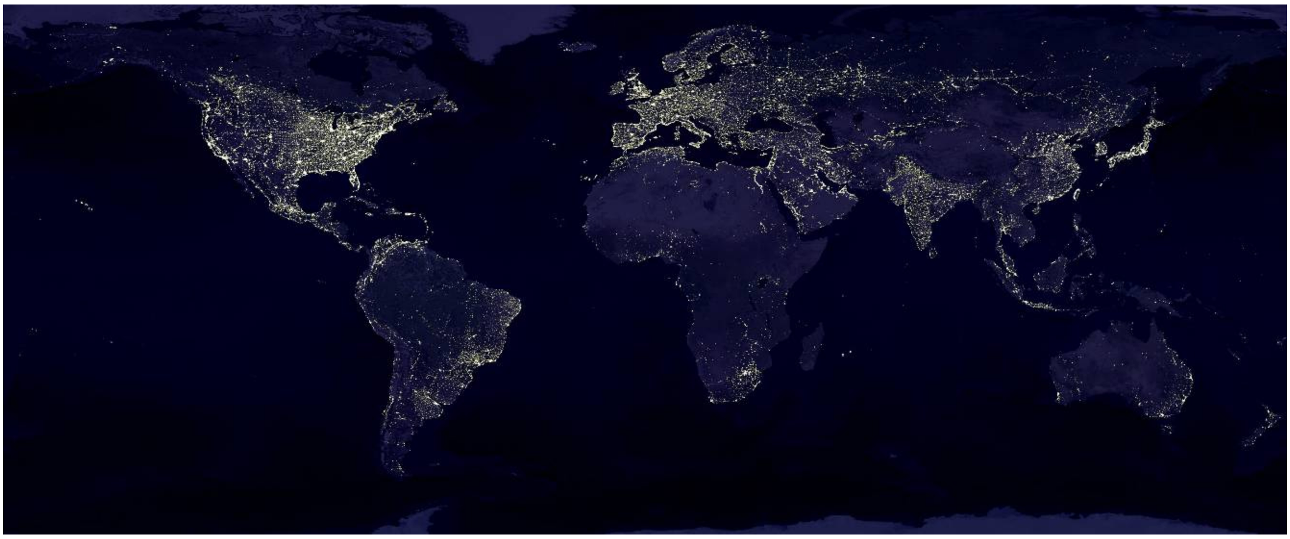

Fig. 1: Earth's city lights. Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC.


ISBN: 978-39502139-4-2 (CD-ROM); ISBN: 978-39502139-5-9 (Print) Editors: Manfred SCHRENK, Vasily V. POPOVICH, Dirk ENGELKE, Pietro ELISEI

Cities and megalopolis have been at the heart of the last Biennale of Architecture held in Venice in 2006. Its Director Richard Burdett has presented the event with these words: "in the moment when the links between architecture and society become at the same time more complex and fragile, there is a need to understand the effects of this growth on human beings and the environment. The way how we, architects, town planners and builders, will have chosen to configure our cities, buildings and public spaces, will determine our reaction to the challenges of climate change and our relation with human rights, justice and the dignity of billions of people migrating to metropolises, looking for jobs and opportunities" (BURDET 2006).

Fig. 2: Biennale di Architettura of Venice (Italy) 2006

The suggestions from the Venice Biennale, and the experimentations and researches carried out on the Milan and Pescara metropolitan areas, suggest us to observe and analyse the complexity of the urban systems from a different point of view. It is necessary to observe urban dynamics, to monitor the flows of resources being absorbed by the city, and the products and the waste that it generates, to understand the relations between people and the urban functions, in a word, to have a dynamic image of the "urban mobility landscape". Today, the studies on cities, on their structure and evolution, are based primarily on remote sensing applications. Through the interpretation of satellite photographs, it is possible to monitor urban growth, variations in land use, and other features of the urban environment. Besides, in many metropolitan areas, there are other elements, such as air quality, being dynamically monitored, and these data are made available in real time. Cities can provide huge databases gathering still data on population, energy consumption, waste production, traffic, mobility, and in general on the urban environment. Only by integrating these databases with dynamic geographical data, it will be possible to understand the actual functioning of the "urban organism".

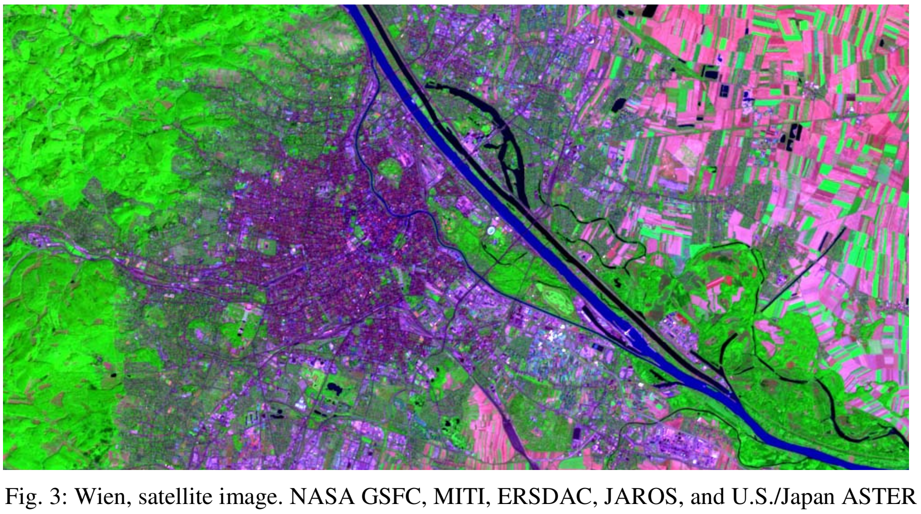

Fig. 3: Wien, satellite image. NASA GSFC, MITI, ERSDAC, JAROS, and U.S./Japan ASTER Science Team.

Geographic Information Systems are the suitable instrument to store, relate, elaborate and synthesise this huge amount of data. In the last years, the European Community has invested many resources in the promotion and establishment of the European Community Geoportal (INSPIRE Directive 2007/2/EC). INSPIRE aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of policies and activities which have a direct or indirect impact on the environment. GIS systems allow us to integrate and analyse statistical and geographical data. The building up of a GIS on the metropolitan areas is based on three main phases: gathering of data, integration of data and building up of a database, analysis and interpretaion of the geodatabase. Today, the first phase is certainly the least problematic, as through the modern monitoring systems we can have a complete view on the urban environment, and in many cases the data are even redundant. A rather more complex operation is building up a geodatabase allowing the interchange and re-use of information (interoperability), and a simple managing and updating of layers. As regards the interpretation of the data, spatial analyses are the tool which is commonly used in urban planning. In the last years, new research fields are developing on the dynamic modelling of city development, which are based on the use of grid data models (CTYROKY & BRADOVA 2007), or on the use of cellular automata models of urban systems.

## 3 CASE STUDY

A recent research was carried out at the University of Siena (the group of eco-dynamics), in collaboration with the Massachusetts Institute of Technology - SENSEable City Laboratory (Canibridge, USA). While exploiting a new technique developed for mobile phone systems, this study provided a spatial analysis of population dynamics in urban areas. This technique was based on mobile phone location data that were georeferential and represented in a series of maps in order to provide instant information on the use of mobile phones in any particular city.

Two case studies were developed: one in the metropolitan area of Milan (a 400 km covered area - 20 x 20 km - with 232 cells) and another in the Coastal Region of Pescara (a 40 km long coastline on the Adriatic sea with 161 cells). In both cases, telephone traffic data was monitored for each antenna that transmits signal to mobile phones (the covered area in named a cell) in the studied area. Each antenna recorded the number of calls made by users per hour. Using a routine procedure, this information is recorded by an Italian telecommunications company for all cells. Based on the information received regarding the position and activity of cells, it is possible to monitor daily variations (in a 24 hour period) and how these variations change over time (cell is in a fixed position, the telephone traffic data is dynamic). Moreover, based on the statistics provided by mobile phone operators (European Infromation Technology Observatory 2007), we are in the position to presume that the telephone traffic in a certain region is indicative of the effective population density (except for approximations which should also be considered). Accuracy is approximately 400-800 meters.

Variations in telephone traffic, monitored in time and space, portray city life (PULSELLI et al. 2007) based on people's actual movements and how they use space and infrastructures. Different ways of using urban space can be monitored and measured over time. The city's dynamics are shown in a series of configurations. Different days were monitored in order to understand how the system is organised and how it changes in time. The discovering of temporal rithms is probably the novelty compared to a conventional description of how the city is used.

A series of maps can record 24 hour trends in the system. There are many possible ways in which this tool can be used to manage, program and solve practical problems in different sectors because this technique illustrates overall behaviour and recognises any disturbances or other events that can cause the results to vary. For example, by envisaging possible perturbations, it is possible to see what effect the closure of a street for roadworks might have on mobility, or how the inauguration of a bar that offers a special coffee mixture can significantly affect the formation of *patterns* in the city (PULSELLI et al. 2006). In fact, it finally can reconfigure the structure and use of space in an entire city district as a perturbation does in a complex system (TIEZZI 2007).

Other probable examples of perturbation that can be analysed using this method include: operations based on incentives to contro1 traffic; initiatives to promote telework; town-planning projects; the creation of wireless networks; the construction of a shopping hall in a city suburb or a new bus route. In real time, these *mobile landscapes* can identify single events including the crowds during public events, football games or concerts, or a drastic reduction in activities in big cities at night or on hot days in the middle of summer.

## 4 RESULTS AND DISCUSSION

In case of Milan, data of mobile phone activity was plotted on a sequence of maps in order to visualize variations of intensity in the 24 hours of a working day. As we had assumed, intensity proportionally corresponds to the presence of people in urban spaces. This allowed us to investigate the general functioning of the metropolitan area of Milan by visualizing urban geo-demography and its variation in time. Considering aggregated data, such as the total daily activity, we provided a unique synthetic map (Figure 4) that shows the whole configuration of social activity in different areas of Milan with different intensity. This information shows how intensively urban spaces are used. Some areas were shown as intensively used, while some others were almost unused during a working day.

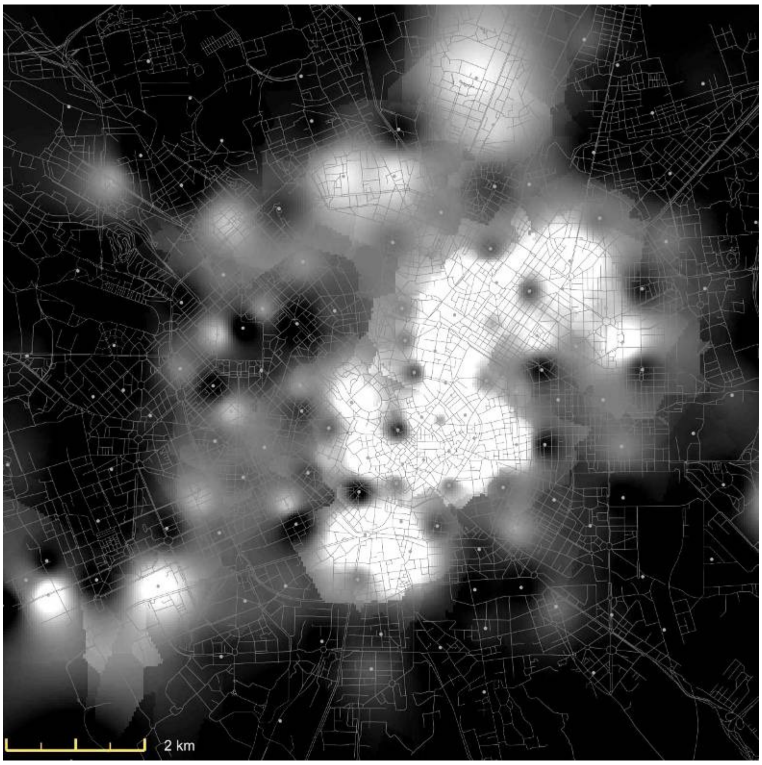


Fig. 4: Synthetic map showing the intensity of activity of an entire day in the Milan metropolitan area. White and black correspond to high and low intensity, respectively.

In the case of Pescara, we analyzed a metropolitan system including the city center of Pescara and a 40km coastline on the Adriatic Sea. Similarly to Milan, we considered the areas with high and low intensity in order to understand how the entire region is used by people in time. Figure 5 shows a sequence of patterns elaborated during a working day in spring.

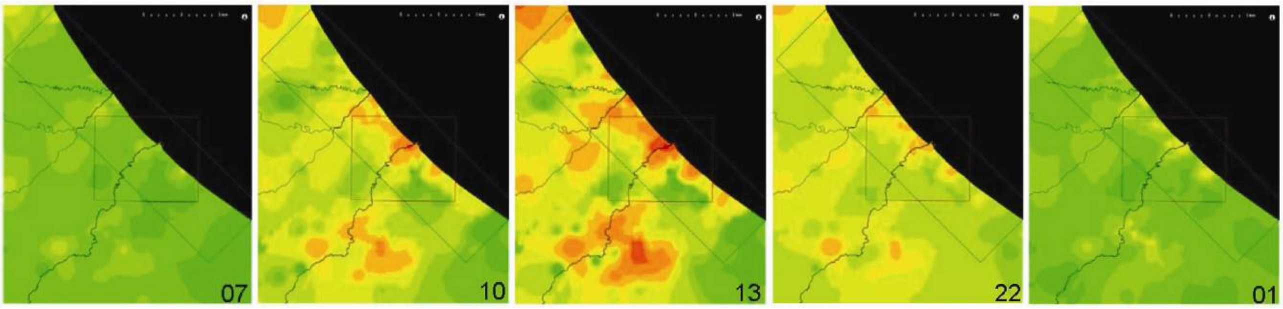


Fig. 5: Sequence of maps showing the intensity of activity in the metropolitan area of Pescara. Red and green correspond to high and low intensity, respectively.

A detailed analysis was conducted in the coastal area, including the city center of Pescara. This was performed in different seasons and resulats show that in summer, especially in August, there is a very different configuration due to the incoming of many turists. This makes increase the activity, and proportionally the density of people in the area, of about 22%. Moreover, while activity in the city center decreases with respect to spring, the intensity is much higher in the peripheral areas along the coast that have their population doubled during summer.

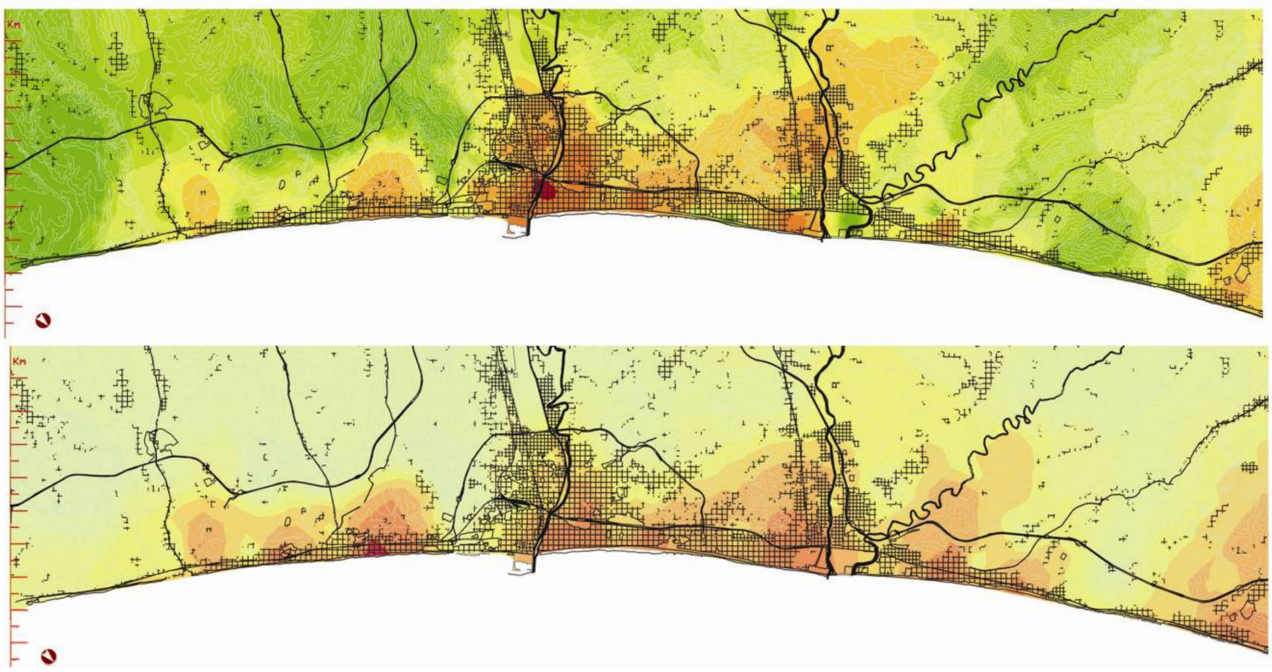

Fig. 6: Synthetic maps showing the intensity of activity in the metropolitan area of Pescara comparing spring and summer seasons. Red corresponds to high intensity. Low intensity is green in spring (up) and yellow in summer (down).

Therefore, difference between spring and summer was monitored and then qualitatively analysed through maps, and even quantitatively analysed by comparing data (number of calls) through tables and diagrams. In the diagram in figure 7 there is the differential index of each location in the coastal area. Numbers represent the increase or decrease of activity in summer with respect to spring.

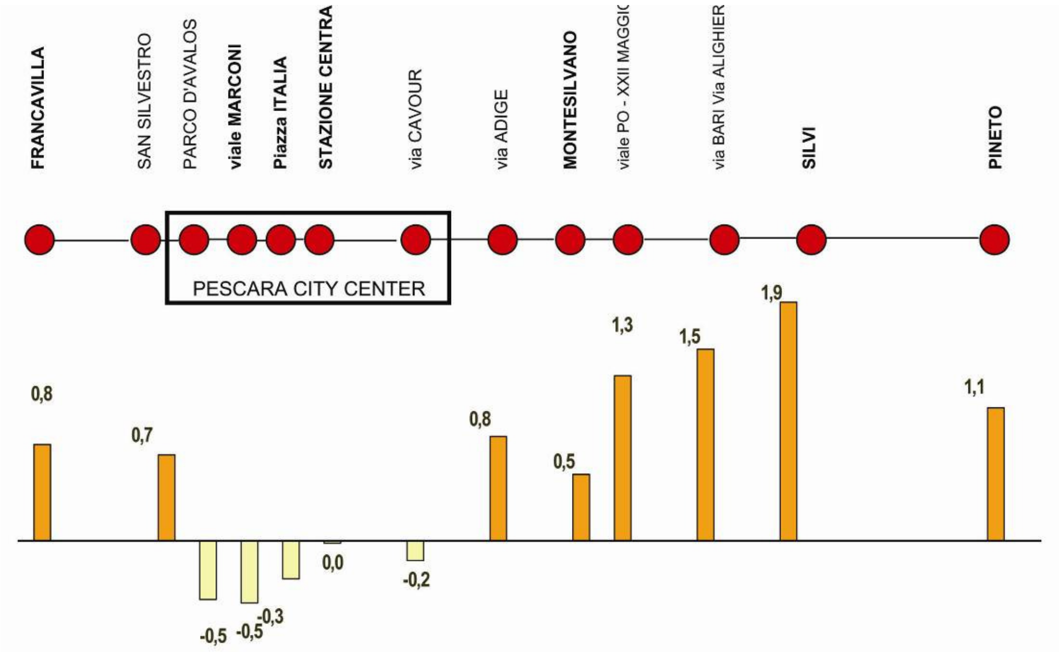


Fig. 7: Compared analysis of summer and spring in the locations of the coastal area. Data represent the variation amount of summer with respect to spring.

## 5 NEXT WORK: A PROPOSAL

The innovative technique for monitoring human mobility paves the way to new analyses and researches on complex urban systems, such as metropolitan areas, polycentric territorial systems and megalopolis. Understanding the functioning of metropolitan systems is essential in order to enhance life quality, to protect the environment and to achieve sustainable development.

The proposal for our future work in this field is to set up an interdisciplinary group of researchers at European level (town planners, sociologists, ecologists, engineers, economists, etc.), who can analyse and compare different European metropolitan areas using both normal survey and monitoring techniques, and the innovative techniques for monitoring the urban dynamics. The most important aspect of the research is to understand how these urban monitoring and modelling systems can become a tool for urban planning and policy making. The real challenge is enhancing connectivity between research and policy making in sustainable development (FP7 Work Programme 2008 – ENV.2008.4.2.3.2).

The overabundance of analytical data and information on the urban environment doesn't facilitate the tasks of the policy makers and urban planners, who often can't manage to interpret the complexity of urban phenomena in an effective and functional way. From this point of view, the GIS systems have to be used not only as tools to manage and map spatial data, but also as Spatial Support Decision Systems (SDSS). The setting up of an SDSS entails, besides the technical elements, a conceptual framework including the knowledge of the context and the ability to evaluate risks, consequences and impacts of any alternative decision (BERTAZZON & LANDO). Real-time monitoring systems can be a support to policy makers and town planners in their setting up and assessment of alternative scenarios of urban development. By using these tools, the operational choices can be more transparent and flexible, because they can be effectively monitored with respect to their effects and impacts on the urban environment.

## 6 CONCLUSION

The aim of the project is to use this information to map the city in real time and to improve our understanding of how modern cities work. This project, originally named Mobile Landscapes project, is an opportunity to understand the shifting complexity of modern cities. It is based on temporal rather than spatial patterns and, for this reason, it refers to a new paradigm for urban studies (RATTI et al. 2006).
The research on metropolitan areas should focus not only on new technologies aimed at analysing and monitoring the urban phenomena, but also on how to use the existing tools and data in order to make decisions and setting sustainable policies for the evolution of the urban systems. Mobile density maps are

part of an experimental project that allows us to check how location-based techniques have an incredible potential to improve the management of services and urban spaces, although this will spark a thorny debate on the issue of privacy. It is important to emphasise that this project only uses aggregate, anonymous data and there have never been any links with specific individuals.
The objective of the study is not to spy on users or promote control over human beings; its aim is to appreciate how location-based services can provide the community with valuable information. No big brother is lurking behind the project and the risk of a possible trend towards sick thoughts is always in the forefront of the authors' mind.

## 7 REFERENCES

AALBORG CHARTER: *Charter of European Cities & Towns Towards Sustainability*. Aalborg, Denmark, 1994. http://ec.europa.eu/environment/urban/pdf/aalborg_charter.pdf

BURDET R: in *Città, Architettura e Società. Catalogue of X Mostra Internazionale di Architettura*, Marsilio, Venezia, 2006.

BERTAZZON S & LANDO F: GIS e paesaggio: dalla scomposizione dei paesaggi reali alla creazione di paesaggi virtuali, http://www.geogr.unipd.it/multimedia/frontgaz/gishtm.htm

CTYROKY J & BRADOVA E: Grid analyses in Prague urban planning, *Real Corp 2007 Proceedings*, Wien, 2007.

NASA, Visible Earth, http://visibleearth.nasa.gov/

PULSELLI R M, Pulselli F M, Marchettini N: The conjunction of non living and living in human systems: why do novelties emerge? *International Journal of Ecodynamics* 2(4) 245-249, 2007.

PULSELLI R M, Ratti C, Tiezzi E: City out of chaos: social patterns and organization in urban systems. *International Journal of* Ecodynamics 1(2) 125-134 2006.

RATTI C, Williams S, Frenchman D, Pulselli R M: Mobile Landscapes: using location data from cell_phones for urban analysis. *Environment & Planning B: Planning and Design* 33(5) 727-748, 2006.

TIEZZI E: *Steps Towards an Evolutionary Physics*. WITpress, Southampton, 2007.

TORRES P M: Geosimulation, informational website, http://www.geosimulation.org/geosim/cellular_automata.htm

UCL CENTRE FOR ADVANCED SPATIAL ANALYSIS, http://www.casa.ucl.ac.uk/