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NEW TECHNOLOGIES AND EO SENSOR DATA BUILD UP KNOWLEDGE FOR A SMART CITY

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ABSTRACT

Established models to represent the territory are moving toward an integrated system of geographically referenced information accessible via web, filled with data coming from different technological platforms ever more efficient, including satellite imaging systems, new solutions for telecommunications and territorial innovative monitoring networks.

This picture is further enhanced by the integration of sensor networks, Internet and mobile phones which allow for the development of monitoring activities, even on real time base. On the other hand, the rapid evolution of Earth Observation systems offers outstanding images that can be interpreted and automatically classified with increasing efficiency.

From this ground, a new cognitive approach arises, and it is based on two innovative paradigms for the knowledge of the territory: City Sensing and City Modelling. Among the benefits of geo-referenced processing of environmental/territorial data, an innovative contribution to governmental paradigms and practices and to planning instruments, both regulative and negotiated, has to be recognized. All this with the support of new communication instruments based on Web 2.0 philosophy.

Keywords: neogeography, new technologies, earth observation, smart city

1 NEOGEOGRAPHY

The pervasive technological growth in recent years has produced a variety of devices for the acquisition of spatial data; costs are increasingly accessible and the deployment and integration on various platforms are easy, too.

An effective knowledge base for a “smart city” requires the optimization of the information flows provided by a wide range of sensors, in real time or not, integrated with the existing “information banks” owned by public administration bodies, in the aim of developing information layers to satisfy the increasing demand for knowledge expressed by the society.

Mobile devices and micro-sensors, characterised by high performance and low power consumption, allow for the construction of technological systems, minimally invasive and widely spread, that can continuously monitor many different parameters. Going from sensors in the woods for fire alarm management, to magnetometers for the analysis of traffic flows, to Unmanned Aerial Vehicles flying at low altitude and with high capacity (Micro-UAV), the potentials deriving from the range of available technological solutions are significantly increased in recent years and the obstacles to their use are now essentially tied to political and cultural issues, rather than cost-benefit impediments.

Within this technological scenario, the numerical and digital cartography has now given way to the enormous spread of images with high spatial and temporal resolution, imposing a new way of representing the territory. A digital map is now made on the basis of a “natural” high-resolution images of the visible spectrum on which some “families of geographical objects” are overlapped. The result is characterised by a double geographic and informative coordinate, i.e. a combination of geometry (WGS84 coordinates) and a text or multimedia content accessible on the Internet (URL).

Like the cartography, environmental monitoring is also going through a development phase towards a new paradigm, i.e. a new approach represented by real-time immersive sensing techniques and social networking; increasing participation in decision-making processes are open for non experts stakeholders thanks to geotagging, geoblogs and web reporting systems.

The spread of positioning technologies (GPS, Wi-Fi, tagging, etc.) and the presence of such features in common devices (smartphones, cameras, video-cameras, browsers) produce new layers of location-aware information and, therefore, new knowledge. The ability to link the GPS-location to a digital photo, for example, is within the reach of many people, even non-expert; the same people actually show how the use of sensors and the “Web 2.0” philosophy create shared knowledge frameworks on the issue of environmental monitoring.

A new context emerges, where “old data”, captured by traditional methods and updated through consolidated protocols, can be integrated with “new data” obtained through sensor networks and the use of Internet. Therefore, a new scenario with important social and cultural implications is outlined.

Many aspects of the revolution brought about in the social system by the Internet are summarized in the concept of “Web 2.0”. Probably used for the first time in 2004 by Tim O'Reilly (Guru of the free software movement) and Dale Dougherty, this term refers to a new way of operating on the Internet with increased interactivity and sharing between information producers and users, whose roles tend to be interchangeable. Intentionally generic, now this concept is associated with a large number of more specific elements like the same social networking, wiki, blog, peer-to-peer, Content Management System and a large number of other conceptual and operational paradigms.

This revolution has set off changes and innovations also on the side of geographic information and of the conceptual models for territorial phenomena. Such innovations are based on interactions and influences between the huge amount of geographical data, both public and “private”, and the technological philosophy of Web 2.0 era.

As Michael Batty and co-authors noted [Batty M. et al., 2010], the success of User Generated Content (UGC) is strongly connected to the widespread use of photo-video personal devices and to the progressive reduction of their cost. According to the authors, the same happens today to the so-called “mapping technologies” as a result of the spread and price reduction of GPS positioning and satellite navigation devices.

The scope of these changes is not only functional, as it may seem; as a matter of fact it constitutes a cultural revolution that is known as “NeoGeography” and that has undoubtedly made many of the concepts and the same technical knowledge on the shape of the Earth much more popular. Nor should one forget the big innovative input given by Google Earth in 2005, when in fact the irreversible transformation of GIS Web oriented applications started.

In this context, it is interesting to understand the effect of the diffusion of technologies on both institutional and socio-economic spheres. The same M. Batty and co-authors, for example, show that when in May 2000 the deliberately introduced error in devices GPS for civilian application has been removed, a significant advantage in the production of end consumer navigation devices has resulted, which in turn has encouraged the development of the cultural change mentioned before.

Currently, location-based features in personal use devices have become numerous, from the ability to store the geographic location of a photo, to the sharing on the web of one's position and so on. The undeniable result is well known: the new generations are perfectly familiar with data associated with a geographic location, with geographic coordinates, optimal shortest path, geo tagging and they can intuitively link all kinds of information to the exact location to which they relate.

After Google Earth/Maps and Virtual Earth, there came also the success of geographic global interface of Flickr[1], together with Google Latitude[2] service, and the various geo-social networking applications, such as TripAdvisor[3] on Facebook or Wikimapia[4], that are perhaps the first significant signs of an irreversible process of change.

A second phase saw non-professional developers taking advantage of free modular web 2.0 services, known as Application Program Interface (API); this gave the final push to the proliferation of geo web applications. At the time being, geo-blogs are countless.

These applications may be the most diverse but their use in the context of e-democracy for the government of the territory are perhaps the most interesting and promising. This new perspective in territorial and environmental information sharing has also produced another interesting cultural change, i.e. the movement for the "liberation" of the data held by public authorities. Perhaps the most important spokesman for this movement is none other than Tim Berners-Lee, considered by many people as the inventor of the Web.

As far as crowdsourcing is concerned, the most known example is the ambitious project OpenStreetMap[5] (OSM). Launched in 2004, the project at the beginning seemed to be not so promising, but now even the most sceptical group has been, or will soon be forced to admit the relevance gained by this initiative.

In this case, like in others, the action of an important business entity has to be highlighted; it is the case of Yahoo, the Web giant, which in 2006 granted the free use of its aerial imagery archive for the collaborative platform OSM, thus giving a decisive push to the success of a very "open" initiative. This operation has eliminated the prohibition to vectorize road maps from copyrighted images; this constraint implied the obligation to acquire the geometry by direct inspection with a GPS logger in order to record the track which then would have been used for the digitization of the map.

Similarly, in a story that has become a symbol of free and open geographic information, in the days following the disastrous earthquake which occurred in Haiti in early 2010, GeoEye, distributor of the images acquired by the IKONOS satellite, released without charge high resolution images of the damaged area with which a vast community of web volunteers produced, in almost no time, the best available maps for the area hit by the tragedy.

We are probably in a mature stage of croudsourcing, that is producing a bulk of informative resources comparable to many institutional databases, in many cases going so far as to exceed institutional quality standards.

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[1] www.flickr.com/map

[2] www.google.com/latitude

[3] www.facebook.com/apps/directory.php#!/CitiesIveVisited

[4] www.wikimapia.org

[5] www.openstreetmap.org

In addition to active contributes to construct and disseminate knowledge, it is also interesting that the web community plays a role in decision-making processes. The process of digital democratization in the government of the territory has already started, and it would not be the same, had we not fully entered the era of NeoGeography.

2 SENSOR NETWORKS AND LIGHT PLATFORMS

The above picture is further enhanced by the integration of sensor networks, Internet and mobile phones which allow for the development of monitoring activities, even on a real time base. All these new possibilities draw a scenario where an increasing number of common objects, with a high degree of interconnection, define the "Internet of Things" (IOT) [Sterling, 2005]. This represents a new technological paradigm based on the extension of Internet access to the world of objects. Objects connected to the network are equipped with sensors that can detect and communicate information, regardless of the presence or absence of a human user, in the strict sense.

These objects are any kind of electronic devices or places such as homes, schools and public squares, containers, clothes etc. equipped with a "tag" by which one can draw a virtual map of the real world and make all such elements communicate. Their recent development is linked to the spread of MEMS transducers (Micro-Electro-Mechanical Systems) installed in small sensors that can measure different phenomena by translating the measured physical quantities in electric pulses.

The last generation "smartphones" belong to this group of objects, which represent advanced technology platforms that allow, for example, the creation of noise maps using built-in microphone, GPS satellite positioning system and a dedicated software[6]; other sensors can monitor personal environmental quality, such as the French Sensaris Senspod[7]. The latter represents the integration of different technologies into a small portable instrument, battery-powered, that can assess the concentration of CO_2, NO_x, temperature, humidity and characterise such measures with GPS position, either transmitting the values to a cell phone or sharing them on a website.

Environmental monitoring strategies based on WSN [Swami et al., 2007] technology (Wireless Sensor Network) are rapidly spreading: a set of sensors, distributed in the environment, form a network aimed at detecting environmental measures. A WSN typically consists of a "base station" connected to some access points (gateway) to which a certain number of sensor nodes is attached (figure 1).

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[6] www.widetag.com/widenoise

[7] www.sensaris.com

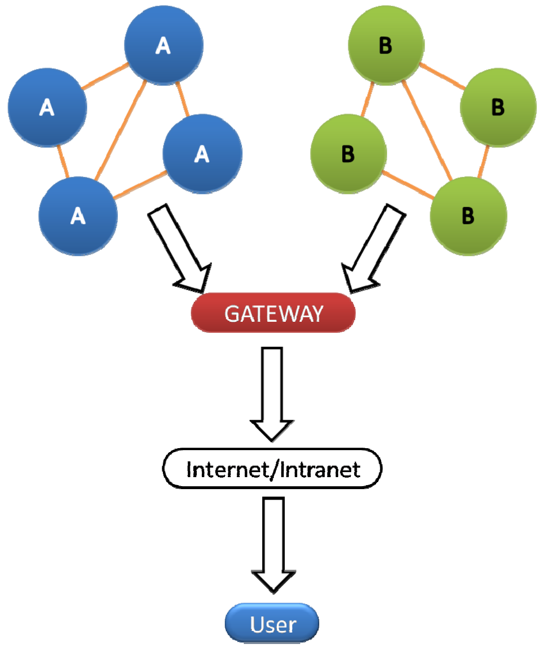

Figure 1 – Wireless Sensor Network schema.

Each sensor node is autonomous, battery-powered and it either forwards sensed data received from other nodes or sends a data stream originated from an installed sensor. The topology of the network is continually evolving: if a node does not transmit or it is not active, the network is kept alive by the change of topology. The WSN are scalable, i.e. the network is able to work with a large number of nodes and the insertion of new nodes is easy and dynamic.

Furthermore, Unmanned Aerial Vehicles are aircrafts, without a human presence on board, remotely piloted from a ground station. Different types of aircrafts belong to the group of UAV: airplanes, helicopters, airplanes, as well as innovative aircraft such as multi-rotor helicopters (quadrocopters and optocopters)[8]. In particular, mini-UAV (less than 2 kg weight) developed in connection to the growing reliability of micro and nano technologies that control the system and the physics of the flight. The possibility to install multiple sensors on board make them usable as sensing platforms in major urban areas, for the analysis of environmental risk and land use changes. They represent a low-cost solution for the prospective and nadir photos, in visible, infrared and thermal spectrum and they can also carry environmental sensors.

The above mentioned technologies can provide real-time values on environmental phenomena; such data can be used for the analysis and the prevention of processes in place or in progress.

3 EARTH OBSERVATION

The rapid development of sensors and the increased spatial and temporal resolution in Earth Observation (EO) offer new opportunities in terms of quality and quantity of information extractable from an image. Remote sensing, declined in different platforms, is a

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[8] http://www.mikrokopter.de/ucwiki/en/MikroKopter

rapidly changing sector, due to the rapid improvement of performance that characterises new sensors.

The increased monitoring need and recent programs of satellite data acquisition have given a significant boost to the launch of new sensors. Under GMES - Global Monitoring for Environment and Security[9], Europe[10] has launched Sentinel and CosmoSkymed[11] programs: the former consists of five different carriers, the first three respectively with radar sensors, multispectral with 13 bands and a dedicated multi-sensor for water monitoring; the latter has four carriers, equipped with synthetic aperture radar and variable ground resolution. The commercial production of optical data recently saw some interesting tools such as GeoEye[12], Quickbird and WorldView[13].

The sensors mounted on aerial platforms saw an even faster innovation process, thanks to the greater number of competitors in the market and to the decreasing operating and investment costs. Resolution of digital metric cameras has rapidly improved and new thermal and multispectral cameras have become available; such instruments let new applications emerge (e.g. precision agriculture) and existing processes improve (e.g. land use maps). Some new sensors have appeared on the market, thus allowing the development of new disciplines; the airborne laser scanner, for example, produces elevation data and three-dimensional models of the territory that can be used to simulate flooding, to analyse the suitability of sites for construction works, etc.

There exists a very important synergy between spatial resolution, temporal resolution, and new treatment algorithms. The short revisiting times of satellites, for example, are particularly significant to detect the changes that occur in a few days or hours; such sudden changes usually involve small areas or small entities that would not be noticeable without an adequate spatial resolution.

The new computing power and the refinement of image classification algorithms would not give satisfactory results if high-resolution images, in terms of space and time and bands of the electromagnetic spectrum, would not be available. The current image processing softwares are able to fully exploit the potential of remote sensing data: not only single pixels are classified, but also the context in which pixel are inserted is analysed and object are formed by aggregating neighbour pixels with similar features[14].

Such object-based classifiers process images in two stages: at first, a process of “multiresolution segmentation” analyses the entire multiband dataset and produces a layer of geometries (objects) by aggregating neighbour pixels according to similarities, tolerances and geometric constraints imposed by the operator. Then, objects are classified on the basis of their radiometric parameters, their context (relationships between neighbour objects, objects of higher or lower hierarchical level), texture parameters and eventually with the contributions of external data (multi-data classification).

The automatic classification is a field with plenty of space to explore, but it is pretty clear that the direction taken will soon see some significant results. The current research strategy is based on the use of ancillary data that can “strengthen” the logic of the classifier; with this

[9] www.gmes.info

[10] http://www.esa.int/esaCP/index.html

[11] http://www.asi.it/it/attivita/osservazione_terra/cosmoskymed

[12] http://www.geoeye.com/CorpSite/

[13] http://www.digitalglobe.com/index.php/88/WorldView-2

[14] http://www.planetek.it/

perspective, the effectiveness of introducing the elevation as a further discriminating parameter is being studied, thanks to DSM and DTM models.

The last frontier of classification algorithms is their transformation into interoperability standards in the aim of providing technical analysis as a web service. Therefore, a processing logic exposed by a node of the network could be applied to datasets exposed by other nodes, producing the result as an additional web service. The Open Geospatial Consortium has long provided standards and specifications for Web Image Classification Service; however, there are still no signs of significant applications.

4 CITY SENSING AND CITY MODELLING

This technological environment, supported by a growing social consciousness and connected to sustainability and accessibility issues, is finding fulfilment in the innovative vision of the Smart Cities[15].

Thanks to the contribution of ICT, cities abandon the role of scenery of daily life, and become a living part of the change, a technological skin innerved by receptors and nerves that allow information exchange between people, objects and complex systems.

The smart city becomes a privileged place for sustainable development, where issues such as traffic, energy consumption, pollution, land degradation etc. are addressed through an innovative and systematic approach, based on communication and information exchange aimed at optimizing processes. This allows for capitalizing on past investments, upgrading and optimizing infrastructures and systems, improving the quality of life and making the city even more accessible.

In order to create an intelligent, technological, interconnected and dynamic system, it is essential to have a high capacity for analysis, synthesis and integration of the huge amount of data produced by different sources. A figure removed from its context does not make sense, but its informative potential can be increased if contextualized within a broader framework and analyzed from different perspectives.

From this ground, there arises a new cognitive approach based on two innovative paradigms for the knowledge of the territory: City Sensing and City Modelling.

City Sensing opens new horizons in the knowledge of the environment, as it integrates spatial and temporal dimensions with the ubiquitous diffusion of receptor nodes in the territory as part of near real time acquisition processes. As for the technological aspect, the use of small technological devices is essential; they have to be miniaturised, portable or even wearable, making citizens active sensors in the territory, thus providing a point of view within the system, and creating a dense, dynamic and updated in real time sensing network.

The real time dimension gives a particular perspective to the paradigm of City Sensing: urban space (but not only urban) has actually become an interconnected space through which data flows, coming from technological devices, can be aggregated and organized within a geographic database, providing relevant representations of what is happening on the territory.

The scenario in which dynamic data are represented does not subsist without the detailed reconstruction of a digital city model, obtained with the most promising high-resolution technologies, according to a paradigm known as City Modelling.

City Modelling techniques are sophisticated survey instruments of great interest; they are able to provide three-dimensional data and extremely dense information layers, are capable of rendering the complexity of the landscape with an approach similar to data mining, i.e. close

[15] http://www.ibm.com/smarterplanet/it/it/sustainable_cities/ideas/

to the acquisition of large amounts of data, independently from an *a priori* domain of investigation, and are free to change according to a specific analysis objective.

Actual technologies allow for the analysis of large amounts of data in real time, thus reducing one of the main subtractive factors to the power of the data; such instruments are contextualized within territorial computer models and, together with the integrated approach of Sensing City - City Modelling, they offer great opportunities in the view of the main objective of governing complex realities such as modern cities.

5 CONCLUSION

Within this particular scenario, the scientific activity of Iuav University of Venice research group in New Technologies and Information on Territory and Environment is focusing on the integration between satellite information and data from wireless sensor networks, wearable sensors and flying micro-devices (drones), in the aim of establishing integrated systems of measurements on the state of the environment and urban contexts.

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