Smart Cities Data Streams Integration: experimenting with Internet of Things and social data flows

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ABSTRACT

Smart cities are nowadays expanding and flourishing worldwide with Internet of Things (IoT), i.e. smart things like sensors and actuators, and mobile devices applications and installations which change the citizens' and authorities' everyday life. Smart cities produce daily huge streams of sensors data while citizens interact with Web and/or mobile devices utilizing social networks. In such a smart city context, new approaches to integrate big data streams from both sensors and social networks are needed to exploit big data production and circulation towards offering innovative solutions and applications. The SmartSantander infrastructure (EU FP7 project) has offered the ground for the SEN2SOC experiment which has integrated sensor and social data streams. This presentation outlines its research and industrial perspective and potential impact.

Categories and Subject Descriptors

J.1. [Computer Applications]: Administrative Data Processing – Government, I.2.4. [Artificial Intelligence]: Knowledge Representation Formalisms and Methods – Semantic networks, I.7.5. [Document and Text Processing]: Document Capture – Document Analysis.

General Terms

Languages, Management, Standardization, Experimentation.

Keywords

Smart City, Data Management, Data Modeling, Visualization, Smart People, Smart Government.

1. INTRODUCTION

Smart city is still a ambiguous term [4], since it refers to mesh metropolitan information and communications technologies (ICT) environments [15]; ICT-based urban features [9, 2]; living labs and large-scale testing beds [14]; while it is used to demonstrate the "smartness footprint" in a city, which is measured with variables like the inhabitants' education level (smart people), government openness and accountability (smart government) etc. [11]. The smart city was initially appeared in 1998 [19, 15] in order to describe urban visualization and today it is used to describe various alternatives of ICT-based solution for the urban space (i.e., digital, virtual, ubiquitous, wireless, eco-cities etc.) [4]. The above approaches address the scale and complexity of the smart city domain, which recently has attracted the international attention by international organizations [4] and big ICT vendors (i.e., CISCO [8], IBM [13] and Alcatel [1]; the electronics (i.e., Hitachi [12]); and construction industries (i.e., GALE, POSCO and HGC Group [1]) are stressed to develop application and products that utilize this emerging market.

The paper demonstrates a real application in smart city domain. More specifically, it uses the findings from the Enterprise Architecture for Digital Cities (EADIC) project, which is funded by the Greek Ministry of Education and investigates the smart city domain for viability features. Moreover, it is based on the research project entitled SEN2SOC: bridging SENsor measurements and SOCial networks interactions via natural language generation for supporting smart city services[1], which was implemented in the smart city of Santander[2] in Spain. This project combined findings from social media data mining and data collected from a locally-installed dense sensor network, in order to enhance decision making of the local administration with accurate information and crowd sourcing. Moreover, Sophisticated software applications can be utilized to engage crowd sourcing in local regions and to transform local into smart communities.

This paper is organized as follows: Section 2 provides a background on the SEC2SOC project. Section 3 demonstrates the software applications, which were developed for the purposes of this project. Section 4 highlights the potential industrial exploitation of this experimental applications. Finally, section 5 ends the paper with conclusions and future directions where we are headed.

2. BACKGROUND

This paper is based on a combination of research findings, which has performed under specific projects. In this section, the context of these projects and the performed experiment is provided.

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[1] http://oswinds.csd.auth.gr/SEN2SOC/

[2] http://www.smartsantander.eu/

2.1 Enterprise Architecture for Digital Cities (EADIC) Project

The purpose of EADIC project concerns the investigation, determination and implementation of a common Enterprise Architecture, which can cover the particular needs of the most (if not of all) the different forms of smart cities.

According to Ducet et al. [10] and to Chief Information Officer [7] the Enterprise Architecture (EA) is an important knowledge base, which describes the strategic mission of an organization, the information and the technologies that are necessary to succeed in the strategic targets, and the migration procedure to handle technological change. In simple words the Enterprise Architecture contains the "blue prints" that describe the principles and the standards for the development of a new service or product. In this context, the EA should not be considered to have information and communications technologies (ICT) as a prerequisite. In almost all cases the EA supports the organization's stakeholders (managers, ICT staff, marketing etc.) providing them with the standards for the development of new infrastructure and of new services; and for the process re-engineering that is necessary for the development of new products and services, and for the change management, which accompanies the new products and services. The EA was first introduced by [20] and it has been –or it is being- followed in almost all significant e-Government cases around the world. Today, EA research concerns coherency, alignment and agility [10] between different projects that are implemented under the same strategic framework.

On the other hand, various forms of smart cities are being developed around the world since 1990: Web or Virtual Cities such as the America on Line cities (USA) and the digital city of Kyoto (Japan); the Knowledge Based Cities the Copenhagen base and the knowledge democracy of Blacksbourg (Scotland); the Broadband Cities such as Beijing (China), Hull (UK), Amsterdam (Holland) etc.; Digital Democracies and Nework Cities such as Eurocities (Europe) and Smart Communities; Smart Cities such as Malta and Dubai; Wireless Cities such as New York and Chicago; Ubiquitous Cities such as New Songdo (South Korea) and Osaka (Japan). All of the above different approaches apply different ICT solutions or they apply the same solutions in different manner in order to achieve their particular targets. However, all various digital cities face common challenges, such as the improvement of everyday life in their local communities, the development of the local market, new job opportunities, access to information and knowledge etc.

According to [4] the smart city can be defined as an ICT based environment in a city area, which focus on the treatment of local community's needs. Most digital cities share common challenges such as: a) the availability of digital services that simplify daily life; b) the transformation of the local community to a "local information society"; c) the direct and indirect collection of local information in order to support the sustainable growth of the local community.

Today, various digital city projects are being evolved worldwide, and in Greece too (e.g. Athens, Trikala, Patras etc.) while networks of digital cities are being structured (e.g. the "Citiesnet " network of eleven (11) cities in central Greece). These projects have many similarities and they develop ICT infrastructure and digital services in the city area. All of these projects concern medium-sized to large scale investments (> €5 million), which are complex to complete, and difficult to be maintained and managed. The New Songdo city project alone, has been implemented during the last thirty years, and demanded a budget of $80 billion, but this project concerns not only the digital but the physical city too. Moreover, the ICT projects in Greece lack in standardization [6] and this particular phenomenon leads to fault project design, management and maintenance.

2.2 SEN2SOC Experiment

SEN2SOC experiment aligned to smart people, smart environment and smart government dimensions of the smart city environment [11, 5]. It has promoted the interaction between sensor and social networking platforms in an effort to offer beneficial exploitation of data produced under the SmartSantander platform, while addressing needs of citizens and authorities. The sensor-to-social interaction is established through the combination of both sensor and social data into meaningful services or functions. Social network behavior regarding the city of Santander is analyzed and the respective results are offered to users of the SEN2SOC applications, whereas, Smart Santander environmental sensor measurements are processed and displayed via alerts generation which updates citizens about the extreme environmental conditions. At the same time, human sensing is activated and SEN2SOC applications users are enabled to express their sensing on their environment (i.e., "users as sensors") or to share environmental alerts in real time on the social network of their preference. Thus, along with sensor or social information provision, the SEN2SOC experiment accommodates input from the community [16, 17, 18].

Sensor and social data flows converge in the SEN2SOC experiment via Web and mobile application prototypes such that::

- Web application essentially constitutes a monitoring tool for the Smart Santander sensor network and offers functions such as: environmental conditions' monitoring; visualization of current or historic sensor data; comparison of data graphs for nearby sensors; and statistical analysis results related to sensor measurements;
- Mobile application presents to its users chromatic maps of various environmental parameters; suggests routes based on favorable environmental conditions; shows alerts regarding extreme environmental values; and informs about trending topics around Santander resulting from the social media content analysis.

Designing an architecture for integrating two different and heterogeneous (sensor and social) data streams required a tailored architecture, depicted in Figure 1, with a component-based approach which has been organized around: the Sensor Data Monitoring, the Social Data Observer, the Interface, the Statistical Analysis, the Web Application, and the Mobile Application components.

These components were proposed in order to meet challenges posed by the two different data streams management and in particular their role is highlighted next:

- The **Sensor Data Monitoring** component retrieves sensor data from the SmartSantander platform with primary tasks: data retrieval, data cleansing, data aggregation, and data storage. Sensor data is spatially aggregated in order to construct the so-called virtual nodes that correspond to various geographic areas that Santander is divided into. Moreover, the Sensor Data Monitoring component implements the alerts generation whenever environmental sensor values exceed certain predefined thresholds (i.e., detection of extreme environmental conditions). Alerts are published to the SEN2SOC social media accounts and are forwarded to the SEN2SOC Mobile Application users in real time.

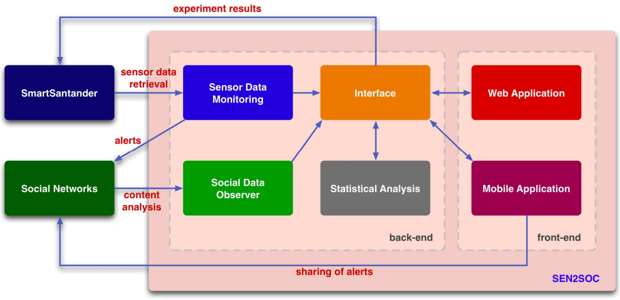

Figure 1. The SEN2SOC architecture

- The **Social Data Observer** component collects Santander geo-located social media content and implements mining on social networks user-generated content (Twitter, Flickr, and Foursquare). Social Data Observer aggregates social media posts and photos based on time and geographic location, and identifies popular topics and photo clusters under semantic similarities and geographic proximity.
- The **Interface** essentially constitutes the intermediary module of the SEN2SOC platform, which: lies in between all components; specifies services that other components can utilize; and allows data communication among SEN2SOC components.
- The **Statistical Analysis** component correlates and analyzes sensor data supporting sensor data mining, statistical analysis, sensor data anomalies detection, and it reports results to the SEN2SOC Web Application. Statistical analysis methods or models applied pertain to: data smoothing; prediction; correlation between two or more sensors; and autocorrelation for detection of repeating patterns.
- The **Web Application** forms a monitoring tool for the SmartSantander sensor network and supports the visualization of real-time and historic sensor data. Other features include the following: detection of closest sensors to the sensor node selected by the user and comparison of the respective data using line charts; prediction models for various environmental parameters; alerts regarding user-configurable thresholds for the desired time period and parameter type.
- The **Mobile Application** offers various services such as: chromatic maps illustrating Santander environmental conditions in real time; route recommendations based on favorable environmental conditions; alerts on extreme environmental conditions; suggestion of areas and points of interest to city citizens and visitors; analysis results of social media users' activity. Furthermore, the Mobile Application implements a mechanism that allows users to express their perception on the present environmental parameters of their current location, thus in a way "validating" Smart Santander sensor measurements.

3. APPLICATIONS UTILIZING SENSOR AND SOCIAL DATA INTEGRATION

The SEN2SOC Web Application has facilitated results summarization and via a user-friendly interface format, selection of a specific feature triggers data collection and analysis from three different sources:

i. the Sensor data monitoring database which collects information for real-time and historic sensor data measured by individual sensor nodes and virtual nodes;
ii. Statistical Analysis process outcome;
iii. Social data database.

An experimentation case study with Heat map representation for all Santander areas is depicted in Figures 2 and 3. Figure 2 has results for the CO measurements, with the red area indicating high level of CO, while Figure 3 has similar heat measurements for temperature.

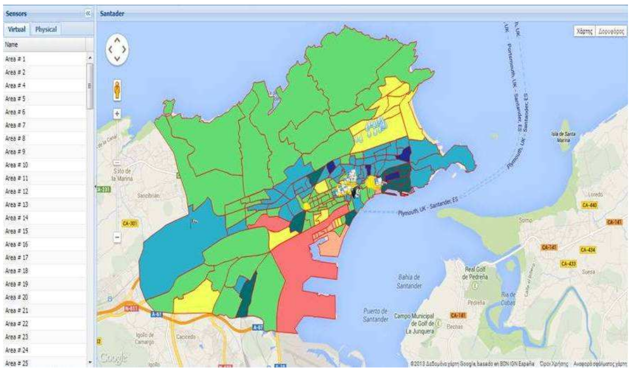

Figure 2. Heat map for CO metric

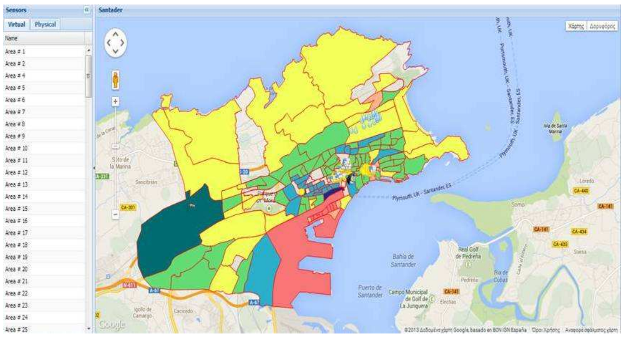

Figure 3. Heat Map for Temperature metric

A data summarization example highlights the Social Data Observer functionality with an indicative example (Figure 4) for a Santander virtual node which depicts photos collected (Flickr) for this area with capabilities given in the applications for social networks users to verify environmental conditions as they emerge in the different Santander city areas.

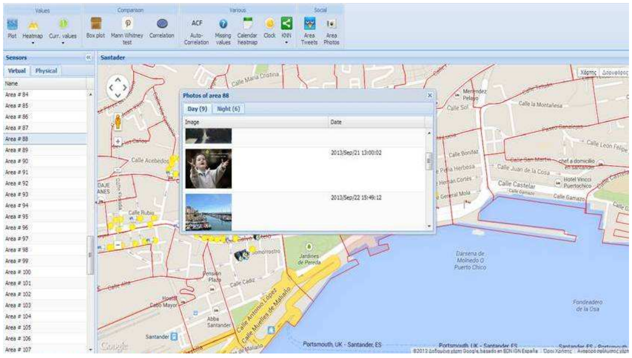

Figure 4. Santander area statistics out of Flickr activity

4. SENSOR AND SOCIAL DATA INTEGRATION: INDUSTRIAL EXPLOITATION

Over the last several years smart cities have gained significant attention in both academia and industry. Seen as complex systems, combined with the requirement to continue to grow in a sustainable manner, the cities represent an excellent ground for deployment and utilization of various ICT based solutions and hence an excellent commercial opportunity.

The Smart Santander is one of the prime examples of the benefits of deployment ICT solutions in general, and in particular of deployment of IoT based solutions. In the course of the project, a number of services were deployed not just for the benefit of the research community, but also for the benefit of the citizens and the city administrations. Real-time monitoring of on-street parking space utilization, environment monitoring (air quality and noise), adaptable street lighting, control of watering schemes in public parks are examples of applications that were made available in collaboration with the participating cities. Further to this, services that enable citizens to report on various events taking place in the city (overfilled waste bins, illegal parking, damaged road and road signs etc.) and thus facilitate faster reaction of the relevant utility companies as well as augmented reality based services to support sightseeing represent further examples of smart city services that were embraced by the city administrations and the citizens.

The commercial exploitation potential of these services is huge and the companies are approaching it from different perspectives. In Smart Santander, large companies like Telefonica and Ericsson provided the key components of the platform enabling storage and semantic annotation of the sensor data (Telefonica's IDAS) and a repository of semantic descriptions of all available sensors in the system thus enabling their dynamic discovery (Resource Directory). Ericsson collaborates actively with the cities on promotion of smart city solutions and has already deployed the ekobus service, a combination of public bus fleet management and environment monitoring service in the city of Pancevo where the Resource Directory is used as one of the key enablers. In collaboration with the city of Novi Sad, a participatory sensing application has been released. A number of small companies are specializing in development and deployment of various hardware components that can be used in the cities, while large companies like Intel and ARM are creating the enablers for development of small, cost and energy efficient hardware components that can be used in IoT systems. At the same time, several cloud based platforms are being developed and deployed as standalone solutions or in collaboration with the mobile operators aiming to facilitate faster deployment and adoption of smart city services. As the social networks have become a mainstream media for interaction and collaboration, the IoT solutions are increasingly focusing on integration of social networks features thus making the smart things social and at the same time enabling fast and efficient information sharing between the members of a community.

5. CONCLUSIONS AND FUTURE THOUGHTS

This paper recognized the size, the complexity and the promises of the rapidly emerged smart city market. It depicted that the smart city term initially appeared early in 1998 in order to describe software applications of local interest and later evolved to various ICT-based solutions for the urban space. Various attributes are used to describe smart cities (virtual, broadband, mobile, digital, wireless, information, ubiquitous, eco etc.), while a smart city measures its “smartness footprint” with its citizens (people); behavior and transportation (mobility); government openness, accountability and efficiency (government); business innovative spirit (economy); sustainable solutions (environment); and quality of life in general (living).

This paper demonstrates a recent experiment, which was performed in the city of Santander, as a combination of the smart Santander project's dense sensor infrastructure and the SEN2SEC European funded research project. Moreover, this paper uses the findings from the EADIC research project, which is funded with Greek funds. EADIC project illustrated the size and the market interest for real ICT applications and solutions for urban spaces, which can secure their viability in economic and acceptance terms. SEN2SEC project utilized the existing dense sensor network, which was installed in the city of Santander in Spain, in order to combine findings from corresponding data collection (i.e., environmental conditions in the urban space), with data collected via social networks from the Santander's inhabitants in order to enhance decision making by the local Government. The experiment was performed in the city of Santander and the software applications offer variable features to the decision makers (i.e., validation of sensors' data with social media information, provided by inhabitants), which can combine smart city infrastructure with crowd sourcing via social media.

The software applications, which were developed under SEN2SEC appear promising for the smart city market and able to attract social interest for smart city capabilities. Moreover, the experiment that was executed in Santander illustrated that smart cities exist and have to combine their infrastructure with broadly accepted applications in order to attract citizens, who have adopted social media in their daily routines. Authors will seek to evolve the SEN2SEC applications and test them in other urban environments in Greece and in other testing beds, while they will combine their evolution with EADIC's determined business models and findings, in order to secure viability.

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