THE "URBAN GEOMATICS FOR BULK INFORMATION GENERATION, DATA ASSESSMENT AND TECHNOLOGY AWARENESS" PROJECT: DETECTION, REPRESENTATION AND ANALYSIS OF THE URBAN SCENARIO CHANGES

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ABSTRACT

About 54% of world population nowadays lives in urban areas and this percentage is expected to increase up to 66% by 2050. Therefore, it is crucial to manage this social and cultural change by collecting, integrating and sharing reliable and open spatial information concerning the urban environments where we leave in. The present availability of huge archives of synthetic aperture radar (SAR) data collected since 1992 by ESA, in conjunction with the available Earth-Observation (EO) optical data, represents a unique possibility to derive valuable information for the understanding of the ongoing urban processes. In this framework, the three-year project financed by the Italian Ministry of Instruction, Research and University, entitled "URBAN GEOmatics for bulk information generation, data assessment and technology awareness" may play a role for the assessment and the development of new replicable methodologies for the study of soil consumption and mobility in urban zones. The paper aims to present some preliminary results achieved during the project, clarifying how the new emerging technologies for managing big EO data are proficient for the investigation of urban processes.

Index Terms— Urban areas, InSAR, soil consumption.

1. INTRODUCTION

Earth's landscapes are rapidly changing, and the human activities represent the main forces that drive such sudden modifications. Monitoring and modeling of these changes are essential for governments, private sector and citizens to make informed decisions on the global challenges that our society is facing. Vital information is being gathered by land, sea, air and space-based Earth Observation (EO) systems. However, the current process of collecting, storing, analyzing and distributing this information remains fragmented, incomplete or redundant [1]. The project URBAN GEOmatics for bulk information generation, data assessment and technology awareness" aims to improve the knowledge of the state-of-the-art and propose innovative solutions for managing geospatial data. It benefits from the huge availability of EO data sources, in terms of integration assessment and awareness, with a particular interest in the urban context. The relevance of this topic is supported by several reports and investigations [2], and by the investments done by the preeminent research centers worldwide. The key aspects of the project concern the application of geospatial methods to data gathered from multiple sources, at different scales and with different temporal repeatability [3]. Specifically, the project focuses on the mobility and soil consumption, which represent two critical aspects in the urban context. The synergy between geospatial sciences and the emerging web technologies, such as Internet of Things (IoT), volunteered/participating geo-crowdsourcing, novel Spatial Data Infrastructures (SDIs) and standard geo Web services is another key aspect to be taken into account. Its added value has been recognized and has attracted a large number of researchers, investments and dedicated events. New data acquisition models are emerging and are providing fast and efficient means for multidimensional spatial data and the geo-referenced information collection. ESA, in particular, is moving towards Open Data and sharing to support the European Commission Copernicus Programme. Data collection and validation require a standard data model and architecture, which is coherent with the latest indications from expert groups and agencies. Collection and validation of spatial data, which have the characteristics of big data, of course require new approaches and solutions. Furthermore, digital reconstruction of the environment and its visual representation is also important to allow augmented reality (e.g. CityGML) and support decision makers.

In this paper, we concentrate on the presentation of the preliminarily achievements of the project, by mostly attaining the investigation of the soil consumption in urban zones as well as the surface deformation that can be linked to urban expansion. The selection of this topic is due to the fact that the modifications induced by soil consumption mechanisms evolve over long-term period of times (20-30 years) and are distributed over wide areas. These characteristics made soil consumption principally suitable to be analyzed by processing long-term sequences of EO data through the generation of time-series. The retrievable information can be enhanced through the use of Volunteered Geographic Information (VGI) data, i.e. the historical archive of the OpenStreetMap project. More specifically, the Small BAseline Subset (SBAS) technique [4],[5] is applied to ESA archives of SAR images that have been collected since 1992 by the ERS, ENVISAT and, more recently, by the new Copernicus Sentinel-1 constellation [6], with the aim to generate long-term time-series of deformation. Furthermore, the temporal changes of the scattering properties (evaluated in terms of normalized radar cross section of the extended scene) of the ground are also investigated. In this framework, the synergic use of SAR and optical data (e.g., collected by the new Sentinel-2 ESA platform [7]-[8]) is beneficial. Urban areas of five major Italian cities have been selected for our investigations: Naples, Milan, Padua, Rome and Turin. Presented results are only preliminary; more extended analyses will be provided in the full paper manuscript.

2. METHODS

The project aims to develop innovative GIS methodologies and tools to exploit the integration of traditional geospatial data, EO and statistics data with new user-generated contents for promoting a more effective management of urban resources and infrastructures. In this framework, both the EO and GIS ERC sub-fields can be considered as proper research contexts for the project. Our cities are becoming very complex systems difficult to control and nowadays, noteworthy decisions are often taken without considering the context and the effects they might have. The spatial information used for monitoring the status of the urban areas is obtained according to diversified data sources: i) The more traditional "urbanscape" (i.e. topographic databases, LiDAR data) or statistical data; ii) the even more accurate and nearly continuous EO data derived from the increasing number of remote sensing platforms/sensors; iii) the new information derived from the Internet of Things (IoT), such as the passive geo-crowdsourced data (SMS, telephone calls, etc.), iv) the user-generated georeferenced contents derived by Web 2.0 applications, such VGI and social networks geo-tagged post. It is worth noting that data derived from the citizen science approach [9] represent an important innovation and added value to the project, thus allowing researchers to obtain a wider perspective on the investigated topics. Nevertheless, their use requires analyzing and solving legal issues about ownership rights and privacy. Once data are collected, another relevant task is the development of procedures to validate them in order to increase awareness about their reliability. Extracted data have to be quality assessed and correctly documented by means of metadata in terms of lineage, spatio-temporal precision, accuracy, consistency, completeness, etc. according to the quality standards defined by the INSPIRE Directive. Data fusion processing techniques [10] are also applied where multiple sources are available. The integration of high volumes of multi-source heterogeneous urban data is another important methodological challenge of the project. To face multi-source data sharing on the Web effectively and efficiently, in compliance with interoperable OGC standards, an acentric distributed SDI architecture has been conceived with multiple end point nodes. Several nodes are deemed for the geospatial data sharing, thus partitioning thematically the physical organization of data. An end point node of the SDI provides the discovery facility by enabling the formulation of content and spatial queries on the metadata, and another node enables the consultation, visualization and analysis of all the distributed geospatial information. Each data sharing node hosts a geo Web server that manages thematically homogenous geospatial data related to whole spatial domain of interests. In such a way, for example, all information about to the characterization of the long-term behavior of the deformation mechanisms in all the urbanized areas will be managed and shared by a single end point of the SDI and will be organized according to a suitable common data model, likewise all information related to soil consumption and mobility will be organized according to their specific agreed common data models and will be shared on the web by distinct end point nodes of the SDI. In this context, standard data models trying to represent the city as a whole (such as the certificated OGC standard CityGML) are considered.

A metadata editor, named EDI, allowing the guided creation of standard INSPIRE and RNDT (the Italian extension) metadata, is available to the data providers for documenting the characteristics, quality, semantics and sharing policy of the managed geospatial data. In the specific cases of time series of image products, generated and shared after

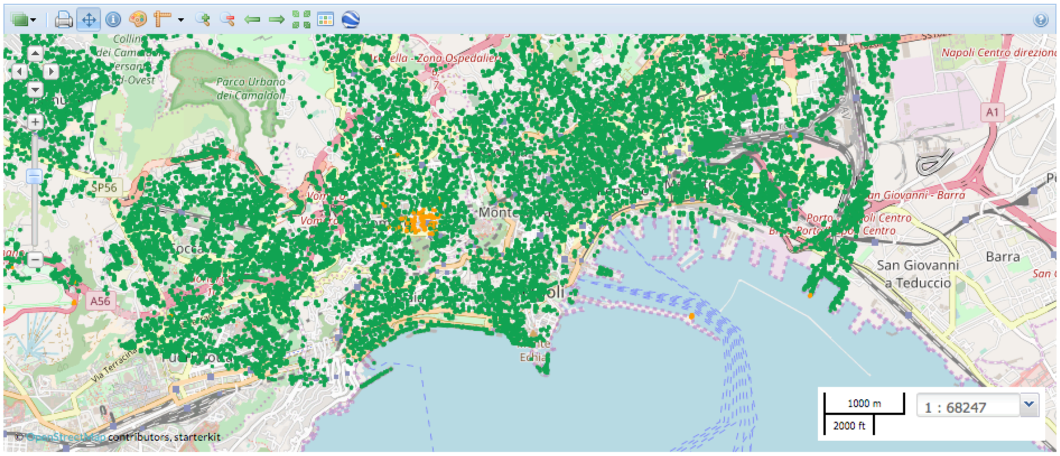

Figure 1 Map of the mean surface deformation velocity occurred from 1992 to 2010 over the urban area of the city of Naples, Italy. The map is superimposed on a GIS platform of the investigated area. The area depicted in orange corresponds to the Vomero quarter that has experienced a significant deformation (on the order of 5 mm/year) during the observation time period.

subsequent time acquisitions, an automatic procedure is implemented to automatically generate the metadata.

To implement the SDI, the use of Free and Open Source (FOS) software is certainly another key aspect of the project to ensure the interoperability, replication and reutilization of the applications. Besides data quality and urbanscape model aspects, standards are also used for the development of geo-services by exploiting OGC standards such as WMS-T (Web Map Service with time support), WFS (Web Feature Service), WCS (Web Coverage Service) and WCPS (Web Coverage Processing Service), and considering the new researches currently addressed on these themes.

As far as the use of synthetic aperture data (SAR) for the characterization of the long-term behavior of the deformation mechanisms in the selected urbanized areas is concerned, the SBAS technique [4] is applied. This well-known technique relies on the availability of a set of co-registered SAR images collected over the same area in different time acquisitions. Starting from the available data, the algorithm selects properly some SAR data pairs, characterized by a short temporal (i.e., the time interval between two acquisitions) and spatial (i.e., the distance between two satellite orbits) baseline. This selection may imply that SAR data pairs, used to produce differential interferograms, could be arranged in a few SB subsets, which are separated by large baselines. Starting from a stack of unwrapped interferograms, the displacement time-series are then retrieved by solving a least-squares minimization problem, based on the application of the singular value decomposition (SVD) method [4]. The residual topographic artifacts, as well as the atmospheric phase screen (APS) signals, are also estimated and filtered out. Additional details on the SBAS algorithm, and the SBAS processing chain, can be found in [11],[12]. Additionally, stacks of co-registered sigma naught maps, obtained by applying a suitable radiometric calibration to SAR images [13] can also be used for the detection of the modification of the urban environment over the time. Accordingly, considering the soil consumption theme, information on the spatial and temporal evolution of urban scenarios can be retrieved with high levels of details through SAR- and InSAR-based analyses. This information are used in conjunction with that recovered on urban land cover and soil consumption in urban areas by using optical EO data classification methods [14] through specific indicators. Soil consumption maps are usually based on the semi-automatic identification of artificial land cover exploiting the spatial and spectral resolutions of optical EO data as Sentinel-2 images (see Figure 2); in addition, ancillary data, such as regional topographic databases, VGI and in situ data, as well as manual photointerpretation of high resolution images are needed to improve the identification of artificial areas.

3. EXPERIMENTAL RESULTS

We present the preliminary results of the project. During its first stages, the focus has been placed on the development of the end point node of the SDI whose objective is to generate and then share on the Web the deformation time-series, obtained through InSAR measurements pertaining the urban zones. To this aim, InSAR data have been supplemented with relevant metadata, describing the principal used InSAR parameters (e.g., the number of used SAR images, the adopted thresholds for the identification of the small baseline InSAR data pairs, etc). Figure 1 shows the results achieved over the urban area of Naples, Italy. The used SAR data were acquired at C band by the ESA ERS and ENVISAT SAR satellite platforms. The applied technique [12] allows performing detailed analyses in urban areas, and permits to detect very spatially localized deformation signals, such as those related to single buildings and public, large infrastructures, highlighting the relative displacements of coherent structures with respect to the average movement of the ground. In particular, the process has involved 164 SAR images, corresponding to Track 36 (descending orbits),

Figure 2 An example of a new building mapped in an urban area with Sentinel-2 images. The numbers of the used bands for the creation of the RGB images are indicated.

acquired from June 1992 to September 2010. Starting from these images, 485 InSAR SB data pairs have been selected, with a maximum perpendicular baseline of 400 m. The topographic phase components have also been removed using an SRTM digital elevation model (DEM) of the area, with a resolution of about 80 m x 80 m.

Geospatial data produced within the project will be collected and coherently organized, visualized and made available to the scientific community through a properly developed web-based tool based on the use of open-source GET-IT platform [15]. GET-IT allows the storage, display and sharing on the network of different types of geographical data, whether digital images, processed maps, data acquired from sensors (observations) or text documents. This is the first open source tool that allows integrated management for these different categories, providing the users with a single working interface allowing personalized protection of the shared data. GET-IT also includes a working environment (EDI) for the creation of metadata and the publication of the same according to INSPIRE standards, thus improving the search and discovery of data and its re-use by organizations and research organizations.

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