GEOSPATIAL MONITORING OF GREEN INFRASTRUCTURE – CASE STUDY ZAGREB, CROATIA

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ABSTRACT

This paper presents current research done under the GEMINI (Geospatial monitoring of green infrastructure using terrestrial, airborne and satellite imagery) project. GEMINI is a scientific project of the Faculty of Geodesy, University of Zagreb and Croatian Forest Research Institute funded by the Croatian science foundation. The project aims to explore new knowledge about the green infrastructure (GI) monitoring. The study area of the research is the capital of Croatia, the city of Zagreb.

One of the main goals of the project is to explore the possibilities of data integration of all available remote sensing platforms: satellite, aerial and UAV (Unmanned Aerial Vehicles) imagery, terrestrial imagery and ground truth data.

UAV-based remote sensing offers great possibilities to acquire field data for monitoring of GI within the urban areas in a fast and easy way. The main objective of this research is to establish an innovative, multidimensional system for monitoring of urban green infrastructure. It will integrate the latest means of data collection (multispectral satellite imagery improved and calibrated with high resolution terrestrial and airborne multispectral sources), advanced spatial analysis with the aim to improve decision support system for better management of urban GI.

This project will improve the current state of the inventory and monitoring of the urban GI to support decision making and preservation of GI benefits, through the establishment of comprehensive procedures for integration of different sources of imagery at different resolution scales: satellite, terrestrial and airborne. This research will focus on novel methods for GI monitoring on the integration of different multispectral imagery sensors. It will require a highly multidisciplinary approach, leading to improvements in methods and procedures for automatic and semi-automatic processing of a large number of geospatial imagery data in the field of urban forest management with expected impact in forestry, arboriculture, urban and geospatial science.

Keywords: remote sensing, photogrammetry, geospatial monitoring, green infrastructure, project GEMINI

INTRODUCTION

Green infrastructure (GI) is a network of natural and semi-natural areas, features and green spaces in rural and urban areas that collectively provide society sustainable, healthy living environment [1]. In Europe, more than two-thirds of the population live in urban areas. It is a highly urbanised continent with slow but steady degradation of urban green vegetation. GI provides various benefits such as environmental (removal of air pollutants, improvement of land quality), social (better health and human well-being, more attractive green cities, enhanced tourism and recreation opportunities), adaptation and mitigation to climate change (mitigation of heat island effects). Today, GI faces harsh growing conditions with heavy traffic patterns and pollution as well as a restriction to water due to increased urbanisation and poor drainage conditions. This caused the vitality of urban trees to fall drastically during the last 30-40 years to an average lifespan of a newly planted tree as low as 7-15 years [2].

City urban GI areas are complex systems composed of numerous interacting components that evolve over multiple spatiotemporal scales (from urban forests and parks to the green roofs, streets, and urban gardens). Satellite remote sensing technology provides an essential data source for mapping such environments but is not sufficient for fully understanding them [3]. More recently, there has been much focus on how GI can be used as a tool for integrated spatial planning to enhance human health and well-being, social cohesion and economic sustainability [4].

Remote sensing techniques are often used for monitoring urban GI as well as using spectral vegetation indices [5], [6]. Thermal remote sensing is widely used in the detection, study, and management of the biomass [7]. The study of urban climate requires frequent and accurate monitoring of land surface temperature (LST), at the local scale. Since currently, no space-borne sensor provides frequent thermal infrared imagery at high spatial resolution, the scientific community is focused on synergistic methods for retrieving LST that can be suitable for urban studies. Synergistic methods that combine the spatial structure of visible and near-infrared observations with the more frequent, but low-resolution surface temperature patterns derived from thermal infrared imagery provide excellent means for obtaining frequent LST estimates at the local scale in cities [8]. A similar method of interpolation of satellite images and temperature measurements at meteorological stations has been successfully applied in agriculture [9]. The potential benefit of using Sentinel-2 satellites in forestry has been investigated, and authors conclude that using data from those satellites is of great importance in the geospatial analysis [10]. An interesting research [11] was related to testing the effect of fusing Sentinel-2 bands on the land-cover classification with emphasis on classification accuracy.

Current development in information technology, electronics and sensors miniaturisation allows mounting multispectral and thermal cameras on unmanned aerial vehicles (UAV) and ground mobile platforms (e.g. automotive vehicle) [12]. UAV-based remote sensing offers great possibilities to acquire the field data for precision agriculture applications in a fast and easy way [13] as well as for other applications such as monitoring of GI within the urban areas. For UAV-based remote sensing without using ground control points, authors obtained external orientation parameters from Global Navigation Satellite Systems receiver mounted on the UAV [14]. In the paper [15] authors researched gimbal influence on the stability of exterior orientation parameters of UAV images.

This paper presents current research done under the GEMINI project. The main objective of this research project is to establish an innovative, multidimensional system for monitoring of urban GI, which integrates the latest means of data collection (multispectral satellite imagery improved and calibrated with high resolution terrestrial and airborne multispectral sources). Also, the goal of the project is to explore the possibilities of data integration of all available remote sensing platforms: satellite, aerial and UAV imagery, terrestrial imagery and ground truth data.

STUDY AREA AND DATA

The study area is the urban area of the city of Zagreb, with the focus on protected green areas inside the city (figure 1). The city of Zagreb consists of several protected areas like Medvednica Nature Park, Park Maksimir, Botanical garden (figure 1c), Lenuzzi's green "horseshoe" as well as significant number of parks with developed and cultivated GI.

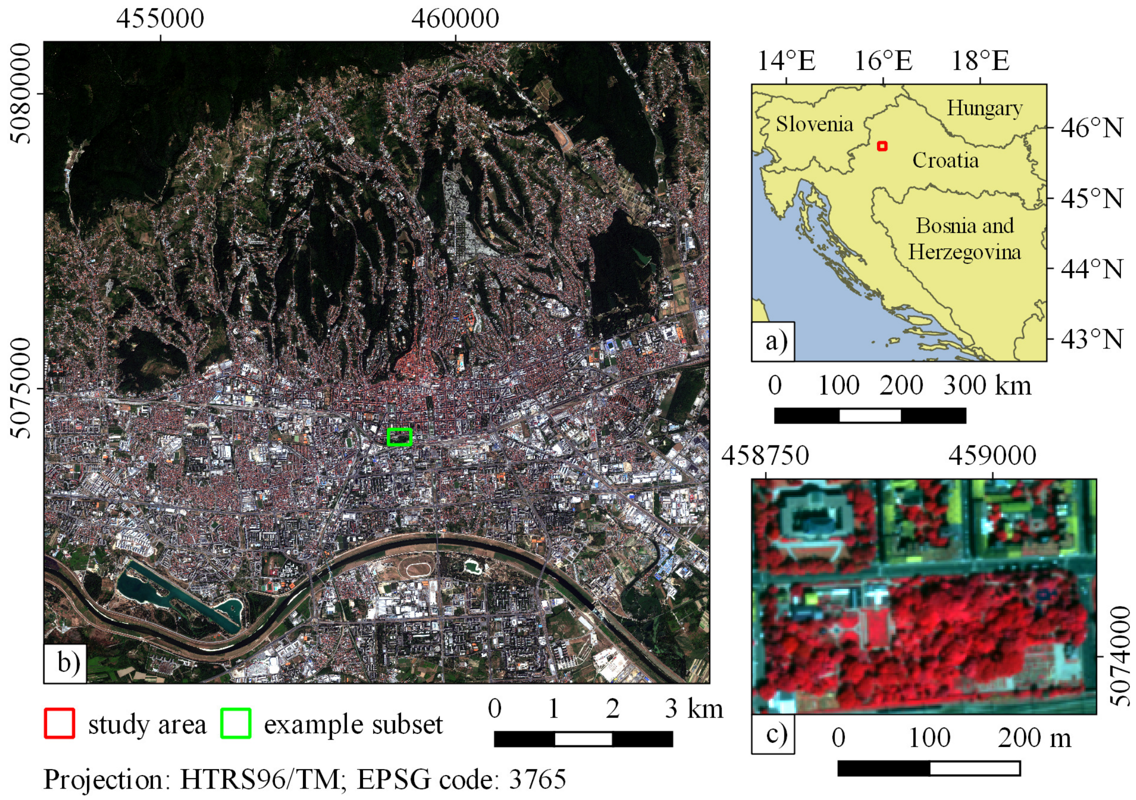

Figure 1. a) Location of the study area; b) study area and example subset location (WorldView-2 'true colour' composite (5–3–2), sensing date: 8.8.2013); c) enlarged example subset (WorldView-2 'false colour' composite (7–5–3), sensing date: 8.8.2013).

The data for this project will be divided into three categories satellite imagery, UAV aerial imagery and terrestrial ground measurements and data. In the first category, all available data from free satellites such as Sentinel, Landsat, ASTER and selected imagery from WorldView 1, 2 and 3 satellites will be included in the project. Data from second and third category will include multispectral data (images and videos) collected from UAVs and automotive vehicle. For the acquisition system calibration, ground measurements, e.g. data from meteorological stations and other sensors will be used.

METHODS

The project will research the potential of multispectral imagery from different sources and time for monitoring and analysing GI in urban areas. Different sources vary from its flexibility of gathering, cost and dynamics of data acquisition. Satellite imagery is mostly used for urban GI monitoring, from health monitoring to urban heat/cold islands detection. The most significant problem in using this approach is the resolution of satellite imagery sources. Depending on the sources, it may vary from several tens of meters to several hundreds of meters. This resolution can be satisfactory for non-urban areas, but it is not good enough in urban areas where buildings and streets occupy most of the city area because most of the collected data does not represent the green infrastructure. This makes hard to distinguish, classify and monitor GI from the rest of the urban area. Sharpening of multispectral channels with the panchromatic channel will be done to explore the usefulness of such images. In contrast to satellite imagery which has the large coverage area but a low resolution, high-resolution imagery from sources closer to ground (UAV and terrestrial) will be used (Figure 2).

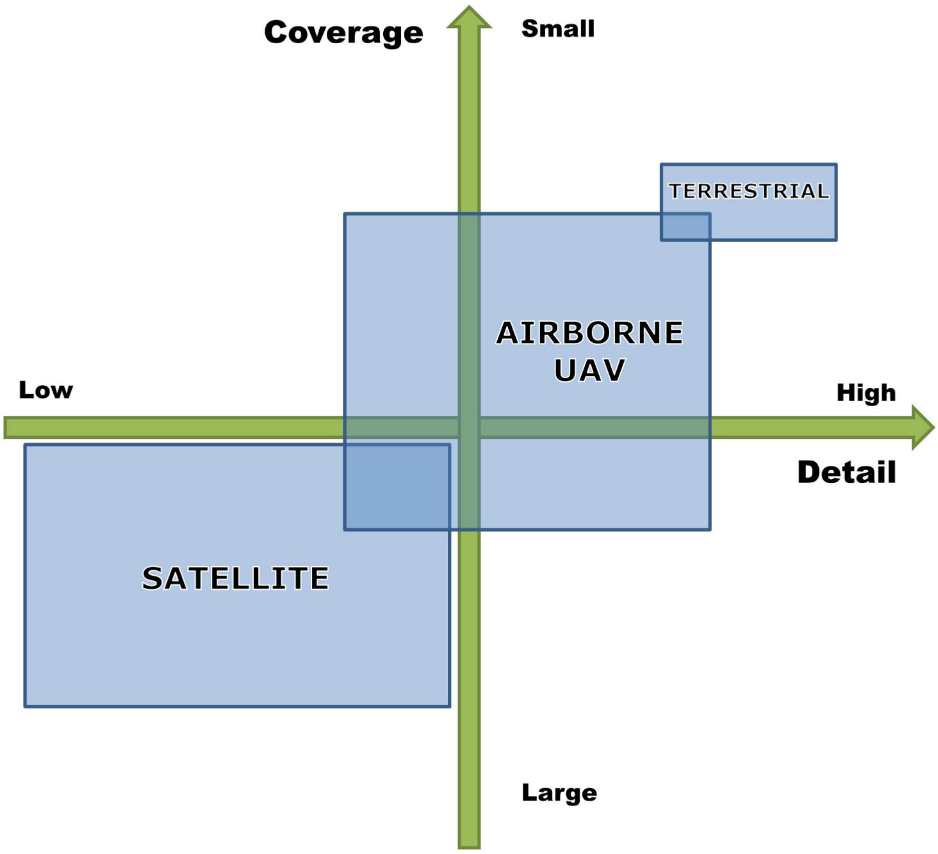

Figure 2. Comparison of different sources of multispectral imagery based on their resolution (detail) and coverage.

These sources vary from resolution to quality and combining, and calibration needs a novel approach. Because of these heterogeneous sources, different possibilities will be analysed, and novel methods for imagery fusion will be developed. Higher resolution images from UAVs and automotive vehicles (georeferenced videos) as well as ground measurement data (e.g. meteorological stations) for example subsets will be used for calibration and evaluation of satellite imagery (Figure 3).

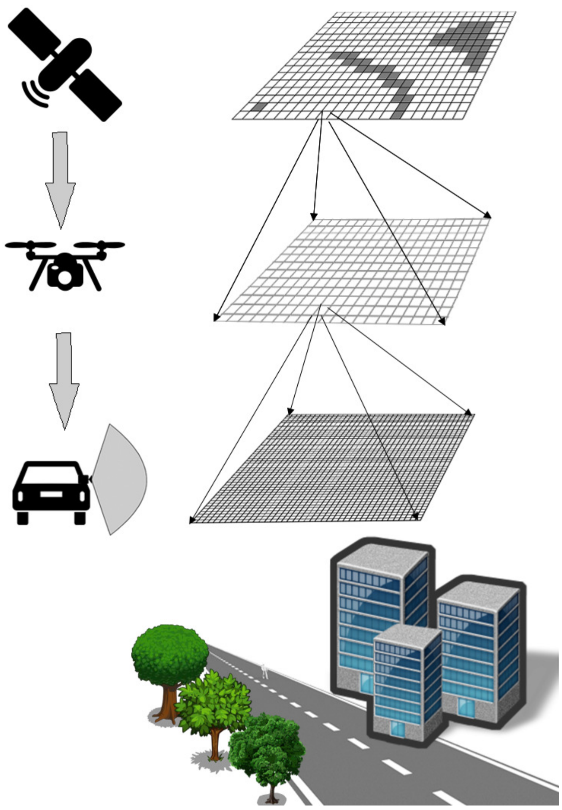

Figure 3. From satellite to terrestrial imagery source resolution.

These selected areas will be used as a training example in the supervised learning to determine control parameters to be used and evaluated in other areas in the city. To make the best possible use of all the collected data and to obtain the best results of the analysis, data fusion methods will be conducted.

Satellite data is easy to acquire for a large urban area, but because of low resolution and many various sensors, it is hard to analyse without ground calibration. Integrating data collected from UAVs and automotive vehicles, fast and more accurate calibration of satellite sensors will be done, in a way that the same principles and methods can be applied to any urban area. For the calibration and integration of various sensors, geospatial tools will be used. This project will be based on open source tools as they are vendor agnostic and can be used anywhere without adding additional cost to the project. The following tools are:

- GRASS GIS, SAGA GIS and Quantum GIS – for data pre-processing, the implementation of remote sensing methods (segmentation, vegetation indices, feature mapping, classification), data fusion, and geospatial analysis;
- R – for imagery pre-processing, data fusion and statistical computing;
- Python – for development and implementation of novel methods for data calibration and fusion;
- GeoServer, PostGIS – for database development, geospatial data analysis;
- MultiSpec, ImageJ and similar programs – for image processing, classification and analysis.

With the evolution of the web technology and the expanding use of the internet-based GIS (webGIS), tremendous amounts of collected imagery will be managed, processed and displayed by a novel webGIS application which can handle such a workload as well as a specially developed indexing method for this specific spatial data. WebGIS technology will offer geospatial computing in the cloud environment through web services to small organisations, public and scientists who are interested in results of the project. They will be able to assemble the resources they need through a web interface without being highly trained specialists in federated computing, requiring access to databases to create virtual ones. As a part of the project, visualisation of the project results will be prepared and presented on a webGIS application as an interactive thematic map.

CONCLUSION

The importance of protected GI areas is continuously growing, mainly because of an increasing interest in recreational zones inside the cities as well as on their outskirts. These areas can be observed from two points of view, as a part of the natural heritage and as popular recreational zones. To preserve them for future generations is necessary to implement a concept of sustainable development in their management. The city of Zagreb has a climate change adaptation plan that focuses on GI, transport, and energy. This strategy framework was introduced into Croatian law and is valid through 2050. As most of the cities have similar issues with GI, at a country level as well as European level, our proposed novel methods and procedures will apply to them.

UAV-based remote sensing offers great possibilities to acquire field data for GI monitoring within the urban areas in a fast and easy way. Recently, various affordable sensors enabled fast and accurate spatial imagery acquisition by UAVs and automotive vehicles. In contrast to images, recorded video clips can be combined with GPS and automatically annotated with geospatial information continuously through time.

This project will improve the current state of the inventory and monitoring of the urban GI to support decision making and preservation of GI benefits, through the establishment of comprehensive procedures for integration of different imagery sources at different resolution scales: satellite, terrestrial and airborne. This research will focus on novel methods for GI monitoring on the integration of different multispectral imagery sensors. The research will require a highly multidisciplinary approach, leading to improvements in methods and procedures for automatic and semi-automatic processing of large number of geospatial imagery data in the field of urban forest management with expected impact in fields such as forestry, arboriculture, urban and geospatial science.

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