Geomatic techniques for utilities consumption analysis in urban areas during emergency periods

by Sara Zollini, Maria Alicandro, Donatella Dominici

Understanding the effects of Covid-19 by studying indirect factors with the synergy of geomatic techniques, namely images from optical sensors mounted on aircraft, UAV and satellites. Proposal of a new methodology to highlight the changes between the periods pre-, during, and post-lockdown.

Fig. 1 – Case study in the Ano Poli of Thessaloniki (Greece).

To understand the influence of Covid-19 to utilities consumption in residential zones, a proposal of methodology to extract parking spots in the urban area of Thessaloniki is presented. Taking advantage of the synergy between different geomatic techniques, change detection analysis can lead to a better management of the territory.

Introduction

At the beginning of 2020, Europe went through an arduous period because of the contagious disease of Covid-19. The disease spread all over the world at incredible rate, so each state, with the aim of reducing and stopping the transmission of coronavirus, adopted extreme restrictions (lockdown) and measures that inevitably affected not only the economic but also the social and psychological life of the citizens. During this period, one of the problems that occurred was the management of building utilities. More specifically, more people started working remotely from their homes instead of the working place, creating numerous problems related to the integrity of everyday utilities, such as power outages, water shortage and insufficient internet connection. The management of this kind of public utilities mainly describes an issue of high complexity because they are not always freely available, or they refer to build-up areas and not to specific buildings. So, it could be of great advantage to study indirect factors, such as the occupation of parking spots in residential areas. The synergy between different geomatic techniques can accomplish this task.
In this work, a proposal of methodology to extract cars occupation is presented. UAV photogrammetry, satellite and aerial remote sensed images are specifically used to achieve this purpose.

Study area

The case study is located in the Municipality of Thessaloniki, in the Ano Poli region, around the old Byzantine church Saint Nicolas Orfanos, in Greece (Figure 1). This is one of the six districts in which the city is divided. This urban block covers an area of 5000 m² and all residential buildings within the urban block have same typology but different age of construction. During the Great Fire in 1917, two thirds of the city of Thessaloniki was destroyed, except for the area of Ano Poli, which remained unscathed. The government commissioned the French architect Ernest Hébrard to design a new urban plan for the burned areas and for the future expansion of the city. Its architecture contrasts with the Byzantine style of Ano Poli, which was even declared UNESCO heritage. The Upper Town preserves Thessaloniki's Ottoman-era attributes, including small stone-paved streets, old city squares, and houses densely built in traditional Greek and Ottoman fashion (Boston, 2014).

Data acquisition

The main and final idea of the work is to analyse the changes happened in the periods before, during and after the lockdown. The available data are aerial orthoimages (LSO) provided by the Greek National Cadastre and acquired in 2015 with 50 cm spatial resolution (pre-lockdown), satellite VHR (Very High Resolution) GaoJing/Superview-1 images acquired in 2020 with 50 cm and 2 m spatial resolution for the panchromatic and multispectral images respectively (during lockdown), and UAV images acquired in 2021 (post-lockdown) with a GSD (Ground Sample Distance) equal to 1.26 cm/pixel. GaoJing/SuperView-1 constellation is composed of 4 identical VHR EO satellites running along the same orbit and phrased 90° from each other. The first two satellites were launched in December 2016 and the second two were launched in January 2018. They are high-resolution commercial satellites designed, developed, and operated by China. GaoJing/SuperView-1 constellation is China's first commercial satellite constellation with high agility and multi-mode imaging capability. When 4 GaoJing/SuperView-1 satellites work concurrently, they can collect over 2 million square kilometres every day and revisiting any target on the Global within 1 day. The optical payload contains a pushbroom type camera with 0.5 m GSD for a panchromatic imagery and 2 m GSD in four MS (Multispectral) bands (red, green, blue and NIR). The swath width of the generated image is 12 km (European Space Agency, 2016). The technical specs are reported in Table 1. This constellation has been used in wide applications and environments, like forest (Chen et al., 2023), mapping (Li et al., 2021), urban areas (Khryaschev and Ivanovsky, 2019), soil (Prokopyeva, 2022), landslide (Xia et al., 2021) and so on.

After the lockdown, on September 9th, 2021, 244 UAV georeferenced images were acquired with a GSD of 1.26 cm/pixel, established by setting a flight altitude of 100 m above the take-off point. The used UAV was the DJI Matrice 300 RTK, with dual receivers that connect to permanent GNSS stations network via 4G (SmartNET Europe by Leica Geosystems). The used sensor is a full frame Zenmuse P1 of 45Mpixels. The longitudinal and transverse overlap was 70%. The UAV and sensor

Imager type	Pushbroom with TDI capability
Spectral bands	PAN: 0.45-0.89 µm B1/blue: 0.45-0.52 µm B2/green: 0.52-0.59 µm B3/red: 0.63-0.69 µm B4/NIR: 0.77-0.89 µm
GSD (Ground Sample Distance) at nadir	PAN: 0.5 m MS: 2 m
Swath width at nadir	12 km
Detector type	CCD array
Data quantization	11 bit
Data positioning accuracy	≤ 20 m
Imaging capacity/day	700,000 km²

Tab. 1: Superview-1 specs.

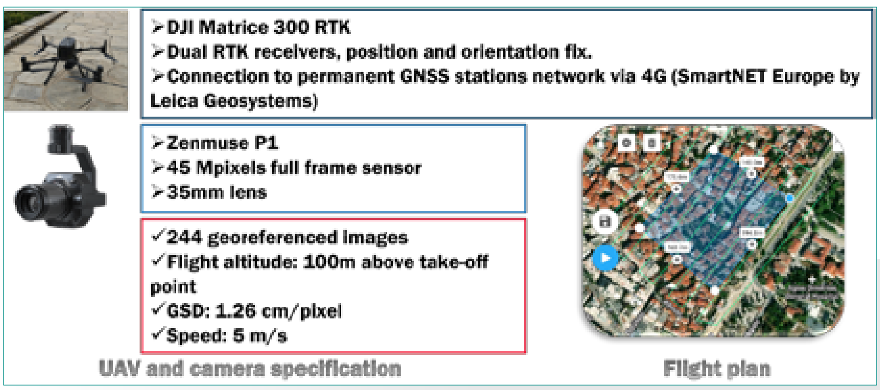

Fig. 2 – UAV and sensor specifications and flight planning for data acquisition.

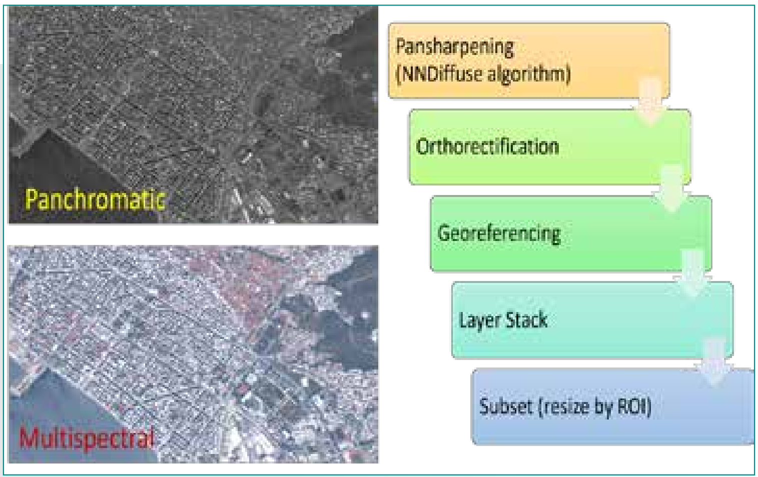

Fig. 3 – GaoJing/Superview-1 panchromatic and multispectral images and the proposed pre-processing.

specifications, as well as the flight plan used to acquire the data are illustrated in Figure 2.

Proposed methodology

The aim of this work is to analyse any changes happened in the period around the lockdown to understand the utilities consumption. So, the proposed methodology consists in applying an object-based image analysis (OBIA) on the images pre-, during and post-covid for a change detection. The research started from the GaoJing/Superview-1 pre-processing. The processing level used for this work is the 1B, the basic product, that is corrected for radiometric and sensor distortion but not geometrically corrected or projected to a plane using a map projection or datum. So, they need to be projected and resampled. For this reason, the first step to be performed is the pansharpening, a fusion technique used to obtain a new image with the spatial resolution of the panchromatic (50 cm) and the spectral resolution of the multispectral one. The NNDiffuse algorithm should be used because it works best when the spectral response function of each multispectral band has minimal overlap with one another, and the combination of all multispectral bands covers the spectral range of the panchromatic raster (Sun et al., 2014). Then, in order to correct the geometry and the spatial position of the image, the orthorectification and georeferencing have to be performed. At the end, a stack of all the layers can be applied and the area of interest is extracted by making a subset on the image. In Figure 3 the original images and the proposed pre-processing is showed.

The research continued with the UAV images, which are treated within the photogrammetric process. The well-known workflow starts from the acquisition phase and then goes through the photogrammetric elaboration. The first step is divided into two main phases, the survey planning, and the data acquisition. The second step include the Structure from Motion, the dense matching and the mesh and texture generation. The final products are the 3D model, the point cloud, the Digital Elevation Model (DEM), and the orthomosaic. The last is used to perform the OBIA. The OBIA consists of two steps, segmentation and classification (Teodoro and Araujo, 2016). In segmentation, pixels with similar features, like brightness, colour, texture are grouped to form vector objects called segments. In the classification, each object is assigned to the class that better define it according to its characteristics. The classification is generally supervised, so a user chooses how much and what classes should be created to train the decision model. This technique is one of the most advantageous for many reasons. Segmentation divides an image into objects as the human eyes do. By creating objects, the computational burden is less than other techniques, like, for example, the pixel-based ones. The

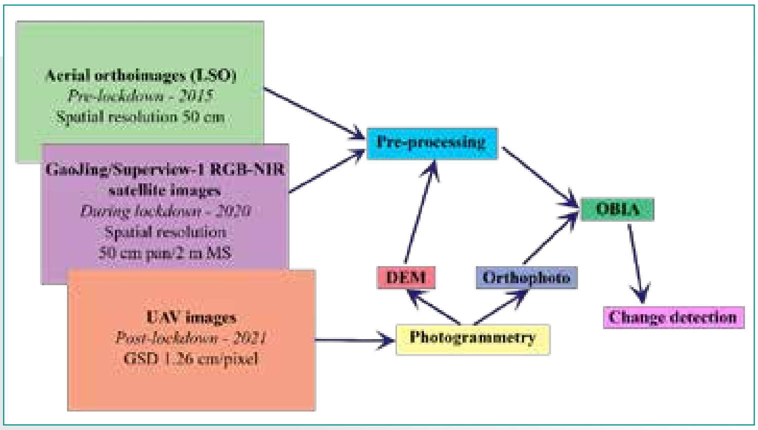

Fig. 4 – Flowchart of the proposed methodology.

segments, composed by many pixels, have additional spectral information compared to the individual pixels (like average, minimum and maximum values, variance and so on). They also contain spatial information, like mutual distances between objects, number of pixels which compose the object, topology, and so forth (Blaschke, 2010). In addition, image objects take into account many features (like shape, texture, relationship with other objects) which are not present in single pixels. At last, segmentation reduces the spectral variability between the classes (Alicandro et al., 2023; Zollini et al., 2020). The proposed methodology is illustrated in Figure 4.

First results

The first results come from the photogrammetric process. The obtained orthomosaic has a final RMS of 0.05 m and a DEM with 5.6 cm/pixel resolution (Figure 5).
On the orthomosaic, the OBIA was applied, but it still requires further investigation, as the classifier presented difficulty in distinguishing cars from the road and the cemetery. What can be done, is to isolate the roads from the rest of the image and apply the OBIA only in that part of the image. As far as the orthomaps acquired in 2015 is concerned, as well as the Superview images, 50 cm resolution could not be enough for car detection. According to the literature, there are two deep learning-based models for vehicle counting from optical satellite images coming from the Pleiades sensor at 50-cm spatial resolution. Both segmentation (Tiramisu) and detection (YOLO, You Only Look Once) architectures were investigated in Froidevaux et al., 2020, but a deeper study of the state of art will be performed. Once the roads are isolated, a subset of the image can be performed, and the surrounding noises can be removed. The DEM was, instead, used to orthorectify and georeferencing the satellite images with the image-to-image technique. 30 GCP were used and a final RMS of 0.768 was achieved. The next step would be applying the OBIA also to the pre-processed Superview-1 and compare eventual changes. Finally, the same procedure will be applied to the aerial images provided by the Greek National Cadastre acquired in 2015 and the final change detection will be performed.

Conclusions and future developments

To conclude, this paper aimed to propose a methodology to indirectly study the effects of Covid-19 on the increase of utilities consumption. The input data refer to the periods pre-, during and post-lockdown and make use of different geomatic techniques, such as satellite remote sensing and UAV photogrammetry. A change detection can be performed by analysing the input images at first with the OBIA, but then, other algorithms within the machine learning world will be also tested and compared. The road extraction leads to understand the occupation of parking spots and, so, the probable presence inside the houses during the working hours. Consequently, the real consumptions can be used to validate the results. Moreover, they can be integrated inside BIM and GIS and could be very helpful for those in charge of the territory management. This can lead to a less expensive and time-consuming analysis for future cities development.

Acknowledgment

The authors would like to thank professors Konstantinos Tokmakidis and Panagiotis Tokmakidis of Aristotle University of Thessaloniki for their precious contribution on UAV data collection. Many thanks also to Vasiliki (Betty) Charalampopoulou and the staff of GSH of Athens, who hosted the authors during the secondments and provided the satellite imagery within the eUMaP project.

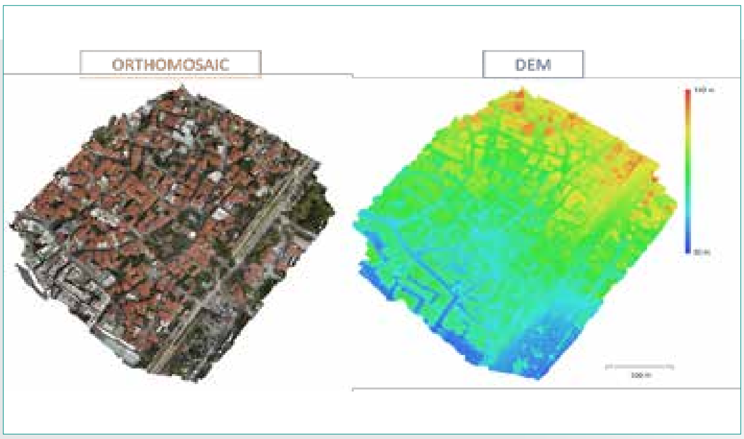

Fig. 5 - Orthomosaic and DEM of Thessaloniki Ano Poli.

BIBLIOGRAPHY

Alicandro, M., Dominici, D., Pascucci, N., Quaresima, R., & Zollini, S. (2023). Enhanced Algorithms to Extract Decay Forms of Concrete Infrastructures from Uav Photogrammetric Data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 48, 9-15.

Blaschke, T. (2010). Object based image analysis for remote sensing. ISPRS J. Photogramm. Remote Sens. 65, 2-16. https://doi.org/10.1016/j.isprsjprs.2009.06.004

Boston, G. (2014). Upper Town or Ano Poli: Historical Thessaloniki https://www.greekboston.com/travel/ano-poli-thessaloniki/ (Accessed 9-11-23).

Chen, X., Shen, X., Cao, L. (2023). Tree Species Classification in Subtropical Natural Forests Using High-Resolution UAV RGB and SuperView-1 Multispectral Imageries Based on Deep Learning Network Approaches: A Case Study within the Baima Snow Mountain National Nature Reserve, China. Remote Sens. 15, 2697. https://doi.org/10.3390/rs15102697

European Space Agency. (2016). GaoJing / SuperView Earth Observation Constellation - eoPortal https://www.eoportal.org/satellite-missions/gaojing#Gaojing-Superview.html.1 (Accessed 9-11-23).

Froidevaux, A., Julier, A., Lifschitz, A., Pham, M. T., Dambreville, R., Lefèvre, S., ... & Huynh, T. L. (2020, September). Vehicle detection and counting from VHR satellite images: Efforts and open issues. In IGARSS 2020-2020 IEEE International Geoscience and Remote Sensing Symposium (pp. 256-259). IEEE.

Khryaschev, V., Ivanovsky, L. (2019). Urban areas analysis using satellite image segmentation and deep neural network. E3S Web Conf. 135, 01064. https://doi.org/10.1051/e3sconf/201913501064

Li, D., Wang, M., Jiang, J. (2021). China's high-resolution optical remote sensing satellites and their mapping applications. Geo-Spat. Inf. Sci. 24, 85-94. https://doi.org/10.1080/10095020.2020.1838957

Prokopyeva, K.O. (2022). The Use of Multi-Temporal High-Resolution Satellite Images to Soil Salinity Assessment of the Solonetzic Complex (Republic of Kalmykia). Arid Ecosyst. 12, 394-406. https://doi.org/10.1134/S2079096122040163

Sun, W., Chen, B., Messinger, D. (2014). Nearest-neighbor diffusion-based pan-sharpening algorithm for spectral images. Opt. Eng. 53, 013107. https://doi.org/10.1117/1.OE.53.1.013107

Teodoro, A.C., Araujo, R. (2016). Comparison of performance of object-based image analysis techniques available in open source software (Spring and Orfeo Toolbox/Monteverdi) considering very high spatial resolution data. J. Appl. Remote Sens. 10, 016011. https://doi.org/10.1117/1.JRS.10.016011

Xia, W., Chen, J., Liu, J., Ma, C., Liu, W. (2021). Landslide Extraction from High-Resolution Remote Sensing Imagery Using Fully Convolutional Spectral–Topographic Fusion Network. Remote Sens. 13, 5116. https://doi.org/10.3390/rs13245116

Zollini, S., Alicandro, M., Dominici, D., Quaresima, R., Giallonardo, M. (2020). UAV Photogrammetry for Concrete Bridge Inspection Using Object-Based Image Analysis (OBIA). Remote Sens. 12, 3180. https://doi.org/10.3390/rs12193180

KEYWORDS

UAV photogrammetry; remote sensing; Superview-1; change detection; Covid-19

ABSTRACT

This paper has the main purpose of proposing a methodology to understand the occupation of parking spots by using the synergy of different geomatic techniques. Aerial, satellites, and UAV data are studied through the OBIA to analyse, by change detection, the main differences pre-, during and post-lockdown due to Covid-19. The first results are really promising and pave the ground for a future automation of the proposed procedure. The results can be also integrated in BIM and GIS to help the management of utilities consumption in emergency periods, and they create a dataset to enhance and increase consumption efficiency in residential areas.

AUTHOR

PhD Eng. Sara Zollini
sara.zollini@univaq.it

PhD Eng. Maria Alicandro
maria.alicandro@univaq.it

Prof. Donatella Dominici
donatella.dominici@univaq.it

DICEAA, Department of Civil, Construction-Architectural and Environmental Engineering, University of L'Aquila, Via G. Gronchi 18, 67100, L'Aquila, Italy

Become a Rheticus® reseller and boost your satellite monitoring services while continuing to manage your business hassle-free.

Rheticus® monitoring the evolution of our earth

Rheticus® is a cloud-based geoinformation service platform for continuous monitoring of land and infrastructures.
A ready-to-use marketable solution for geomatics companies enabling industry-focused services for utilities, energy, transportation, engineering, mining, urban planning, land and marine environment, wildfires, aquaculture and precision farming.
Rheticus® is **available worldwide with an innovative yearly subscription model:** this allows you to enable new business opportunities without problems, because you can always count on our **personalized Sales and Technical support** and on the **experience of over 25 years** of Planetek Italia.

Join us on
www.rheticus.eu

Winner of
WORLD **SMART CITY AWARDS** 2019