DETECTIONS OF BUILDINGSDIGITAL SURFACE MODELS DEFORMATIONS GENERATED FROM DRONES NADIR IMAGES

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ABSTRACT

Unmanned aerial vehicles (UAVs) are becoming very popular and useful for several applications, Due to their accessibility to any target and high-spatial resolution of acquired images.

In this study, UAV application in geospatial technology for 3D urban modeling, for building assessment and deformations detection due to nadir images processing.

This work shows the results of an approach that used a photogrammetric UAV platform to build a recent urban DSM and estimate its expansion by building a second predicted urban DSM. The methodology discusses the use of a low-cost unmanned aerial vehicle (UAV)-based remote sensing system for spatiotemporal urban DSM modeling constituting a good platform for deformations building assessment, urban management, and infrastructure development.

As a result of this project generated a series of digital surface models, a DSM UAV based, a modified DSM-T excluded from buildings, a corrected recent DSM-R and a predicted DSM-P of a fully built study area. Finally, produced DSM buildings deformations map based on the difference between DSM UAV and DSM-R.

KEYWORDS: UAV, DSM, Urban Modeling.

1. INTRODUCTION

The development of unmanned aerial vehicle (UAV) technology has enabled great remote sensing platforms by acquiring aerial imagesfrom a different type of sensors. Many studies have been published on the use of aerial imagery for different applications, such as vegetation mapping[4], structural damage assessment [2], multiscale terrain analysis and temperature modeling [1]and many others. In this paper, the use of UAVs aerial images combined with Geographic Information Systems (GIS), allowed the generation of planar and altitudinal spatial informationwith positional quality at the centimeter level. For this scenario, the Structure from Motion (SFM), has been wildly used as a modern tool for UAV's images processing [6].

The altitudinal data generated from SFM technologies are usually 3D point clouds, theirinterpolation produces Digital Surface Models (DSM).

In this study, we generated a raw DSM of a half urbanized area in Lebanon based only on horizontal aerial photography. Usually, for modeling urbanized area to avoid models deformation and to obtain real buildings texture we should add oblique aerial images to the processing, it means that our obtained DSM contains a lack of data due to the missing point clouds on the extremity of the model.

In urban areas, the lack of data and model deformation are recognized visually, with the application of spatial filters these errors could be detected and removed very easily.

The methodology of our study could solve the problem of buildings deformation detection by generating a recent DSM from UAV aerial images and based to cadastral and building information to rebuilt an old DSM and to predict a future one.

The second step correcting the UAV generated DSM by the application of some GIS tools to obtain a recent clean one.

2. MATERIALS AND METHODS

Not far from the capital of Lebanon in a half urbanized area in Zouk Mosbeh with some scattered unbuilt green parcelsfigure 1.

Fig.1: Digital ortho model (DOM) of the study area.

Figure 1a mosaic of aerial images of the study area shows green unbuilt areas and some buildings with diverse height and forms due to the parcel shape. The data sets of the study are only UAV aerial images and a cadastral map from the Lebanese cadastral service.

The project is constituted from two parts, field and office work, the field partbegins with the study area site recognition and ends by UAV landing, as a preflight step and for the geo-referencing of the model to stereographic projectionwe surveyed 8 GCP points by a differentialGNSS receiver with centimetric precision.The UAV used was a DJI Phantom 3with 14-megapixelcamera, fliedat a height of 130 m above ground from the taking off point, resulting on a Ground Sample Distance – GSD equal 4 cm, the flight path designed in Litchi autopilot application andimages forward and side overlaps were approximately 80% and 70% respectively.

After completing the mission, the second part of office work (photogrammetric processing) begins with the use of Agisoft Photoscan software to automatically perform a bundle adjustment, points cloud, DSMin figure 2b, and Digital Ortho Model (DOM) generationsfigure 1.

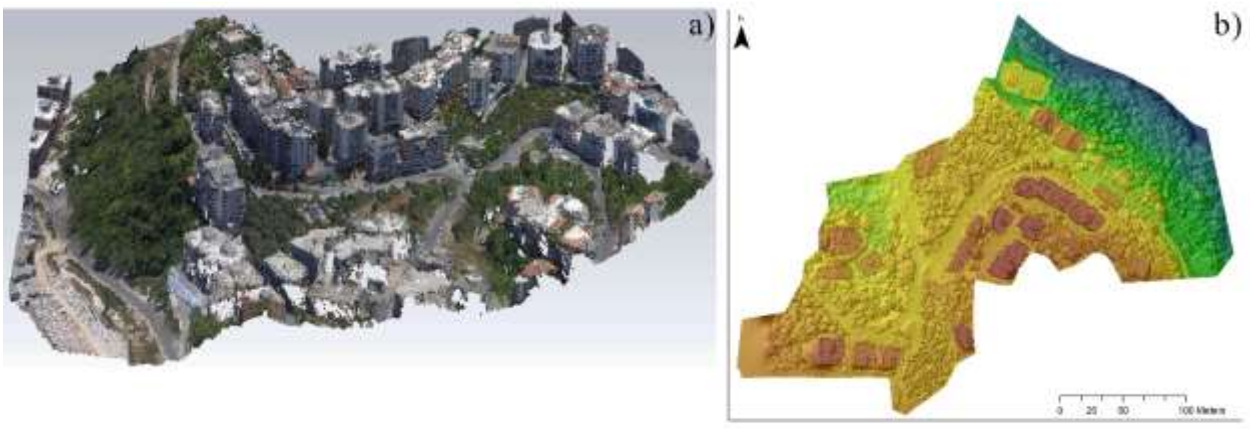

Fig.2: a) 3D colored point clouds generated from aerial images, b) DSM UAV based interpolated from 3D point clouds.

Figure 2a shows a perspective view of the 17.5 million colored 3D point clouds generated from 79 aerial frames, the interpolation of these points leads to a high spatial resolution DSM of 9.5 cm from a point density of 108 points/ sq. m figure 2b.

The DSM generated from UAV horizontal images shows deformations and artifacts in 3D buildings models, these errors could be removedusing oblique imagery by adding more side images to the photogrammetry processing. Oblique imagery is a powerful source of geodata with various applications and potential, particularly over urban areas, oblique imagery allows the generation of denser 3D point clouds, on vertical elements (buildings façades), with higher reliability with respect to traditional vertical acquisitions [5].

Our purpose is to correct these building deformations in the DSM by extracting building's roofs from the geodesic geomorphological filter and adding from points cloud their heights to attributes, this operation constitutes a recent building database.

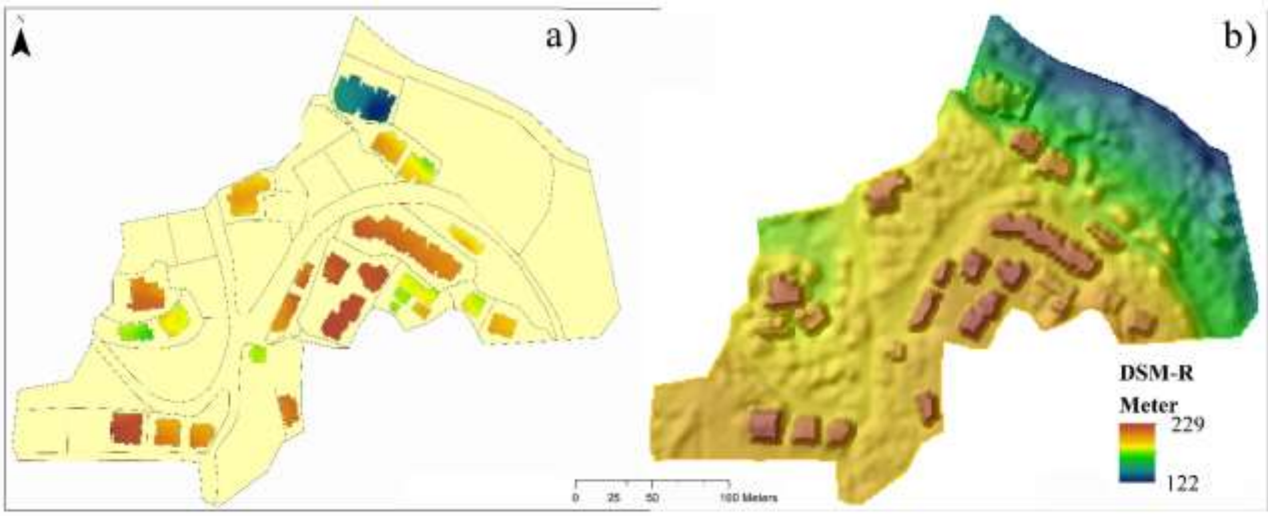

Fig.3: a) recentbuildings digital model (BDM-R) draped on the cadastral map, b) the corrected recent DSM-R.

The extracted building database was checked and corrected from the DOM, as the footprints of the buildings form their projection to the ground otherwise a height extrusion forms their true recent digital model (BDM-R) figure 3a.

The DSM UAV based with a high spatial resolution of 9.5 cm resampled to one meter and excluded from building by passing a 3 × 3 morphological erosion filter with a diameter of the structuring element of the estimated largest cross-section of a building is applied to theDSM[3]. In this case, all roof points of the buildings get replaced by the lowest (ground) value in distance of half the diameter of the structuring element to obtain a DSM-T containing ground and trees elevations.

By combining the two produced recent buildings digital models (BDM-R) and DSM-T we got a new DSM-R rectified expressing the recent building situation figure 3b.

3. DISCUSSIONS AND RESULTS

After correcting the recent digital surface model by following the steps in the workflow of figure 4, urban planning predicted digital model was designed based on DSM-T by adding urban units to the empty parcels and giving them a unique height of 15 meters to form a new predicted Digital Building Model (BDM-P).

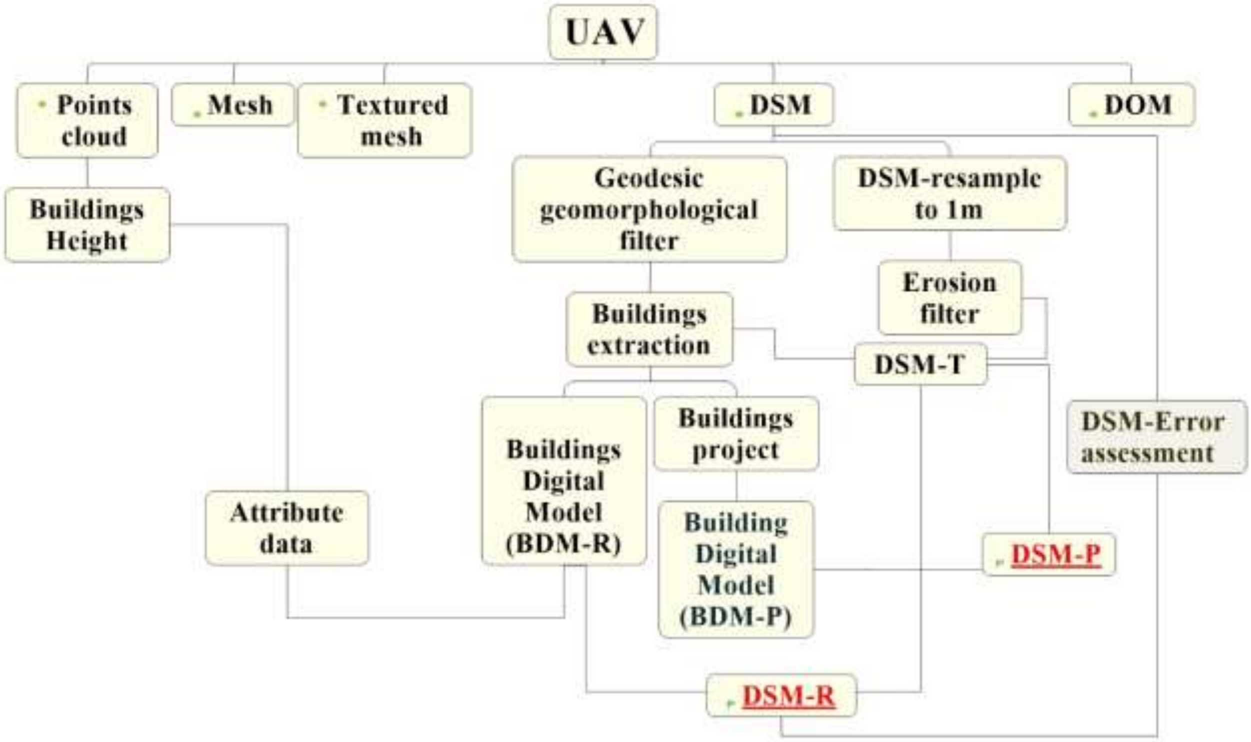

Fig.4: the workflow of the methodology followed in our study.

The BDM-P combined with DSM-T constitutes a future project urban digital surface model (DSM-P), this DSM-P could be a reconstruction project of an urban area destructed from adisaster.

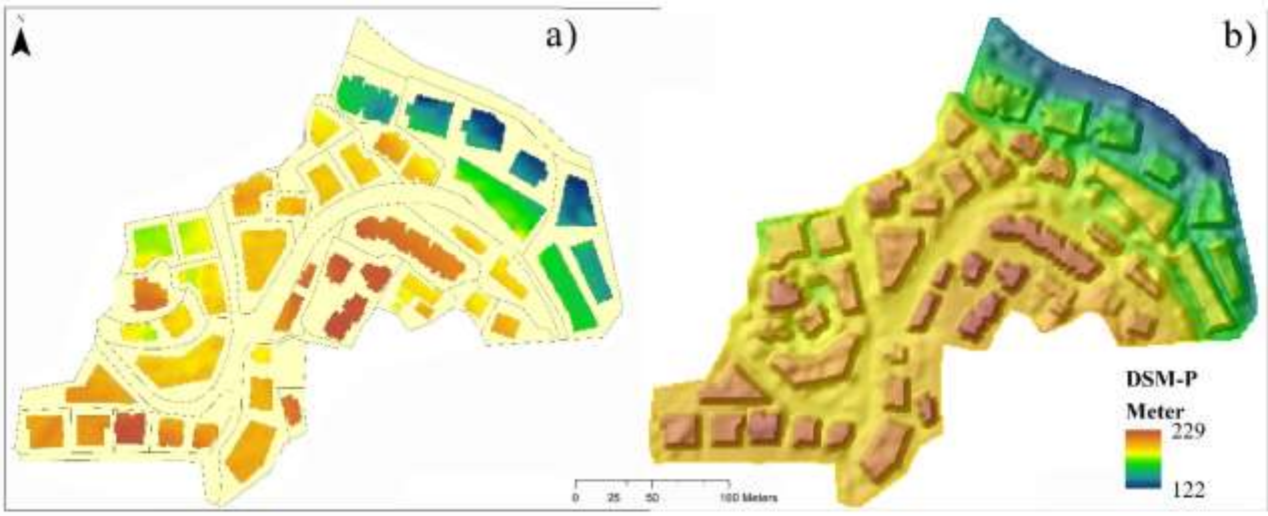

Fig.5: a) predicted buildings digital model (BDM-P) draped on the cadastral map, b) the predicted DSM-P.

The predicted building digital model BDM-P in figure 5b with 47 urban units, 22 of them predicted to constitute a future urban model. The BDM-P combined with DSM-T to build the Predicted Digital Surface Model(DSM-P).

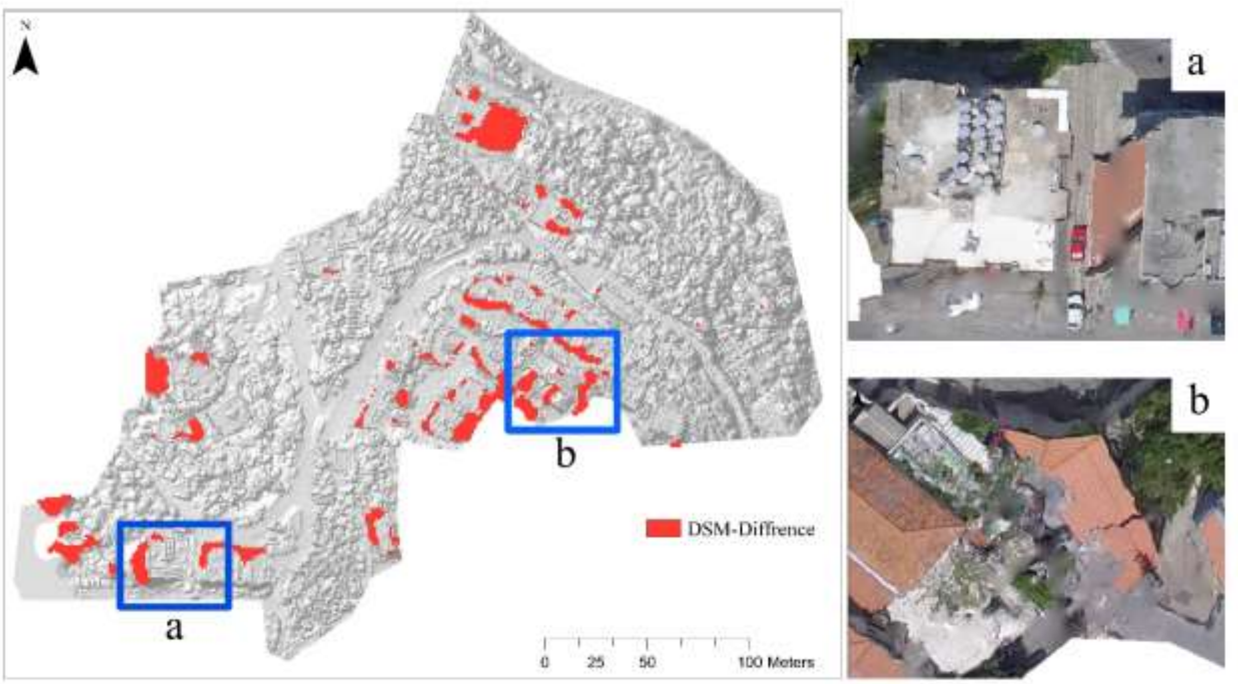

Fig.6: a) DSM deformations on the façade of a building, b) DSM deformation on the top of a building.

Horizontal UAV images for 3D urban project contains artifacts and deformations due to the insufficient number of images otherwise oblique UAV images 3D projects cover all building side and generate a clean 3D Model empty from deformation, to highlight buildings deformations in the UAV based DSM and corrected in DSM-R, in raster calculator we applied a subtraction between the deformed and the corrected digital models.

As result we got a new map showing in red the deformations in buildings figure 6, deformation in the façade of the building showed in figure 6a and figure 6b showed the deformations on the top of the building.

4. CONCLUSION

UAV database and geospatial technology could help researchers as a new approach to generate information and improve decision making. The use of a UAV platform offered flexibility and agility for image acquisition, turning viable the study of the mentioned phenomenon in the existing conditions.

Considering the results of this study, a corrected recent DSM-R of the actual form of the urban units and it could form a good building assessment, besides a new predicted DSM-P acting as a future project for urban design.

The methodology applied in this research could be an important platform for temporal analysis and inspection based on multi-temporal DSM terrain analysis.

The subtraction of DSM UAV based and the corrected recent DSM-R highlight DSM deformations. The creation of a DSM aerial imagery based has enabledspatial analysisfor disaster science, environmental management, and urban planning.

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