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SfM photogrammetry for monitoring urban developments

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ABSTRACT

Structure-from-Motion (SfM) Photogrammetry is a valid alternative to traditional photogrammetric methods. This study presents a simplified approach for mapping and monitoring of urban developments in a section of Kuje Area Council in Abuja, Nigeria, utilizing SfM Photogrammetry alongside Google Earth Historical Imagery. The capture of the UAV images in year 2020 was followed by the acquisition of the 2005 Google earth historical image, which was used in tracking and ascertaining the development over time. The two images (the 2020 and the 2005 images) were geometrically aligned to enhance comparison. Features identifiable in both images such as buildings and plots were vectorized. The analysis revealed that the Kuje Area Council has witnessed 120 building constructions in the past 15 years which on average implies 8 building constructions per year. The maps produced can facilitate well informed urban planning in the area.

1. Introduction

Structure-from-Motion (SfM) Photogrammetry is a valid alternative to traditional photogrammetric methods, Terrestrial Laser Scanning (TLS) and Airborne Laser Scanning (ALS) (Raoult et al., 2017). Its ability to extract high resolution and accurate spatial data using cheap consumer-grade digital cameras and smartphone cameras appears truly remarkable (Fonstad et al., 2013; Tarolli, 2014).

The deliverables of SfM include orthophotos, 3D point clouds and digital surface models (DSMs). With orthophotos, one can create maps and models of properties, construction projects, and earthworks. Orthophotos can also be used to extract features manually or semi-automatically for map creation or update (Koeva et al., 2018; Gbopa et al., 2021).

Orthophotos are extremely valuable for manual or semi-automatic feature extraction for map production or updating (Sarp et al., 2014), as well as for change detection (Gbopa et al., 2021; Koeva et al., 2018; Sarp et al., 2014). For city monitoring and disaster response, as well as updating maps and three-dimensional models, urban change detection is critical (Qin, 2014). When compared to satellite images, the use of unmanned aerial vehicle (UAV) images for change detection analysis offers obvious benefits in terms of spatiotemporal resolution and cloudlessness (Yao et al., 2019). Images with high spatial resolution are especially preferred for the accurate processing of variations in urban land cover. This requirement can be met by UAVs through the provision of precise data measurements (Jumaat et al., 2018; Franklin and Wulder, 2002).

This study presents a simplified approach for mapping and monitoring of urban developments in a section of Kuje Area Council in Abuja, Nigeria, utilizing SfM photogrammetry and Google Earth historical imagery.

2. Methods

2.1. Study area

The Kuje Area Council is one of the main sub-catchments of Abuja, the Federal Capital Territory (FCT) of Nigeria and is shown in Fig. 1 below. Kuje has an area of 1,644 km^2 and a population of 97,367 as of the 2006 census. Abuja is the capital city of Nigeria located in the center of the country within the Federal Capital Territory (FCT). Abuja's geography is defined by Aso Rock, a 400-meter (1,300 ft) monolith left by water erosion.

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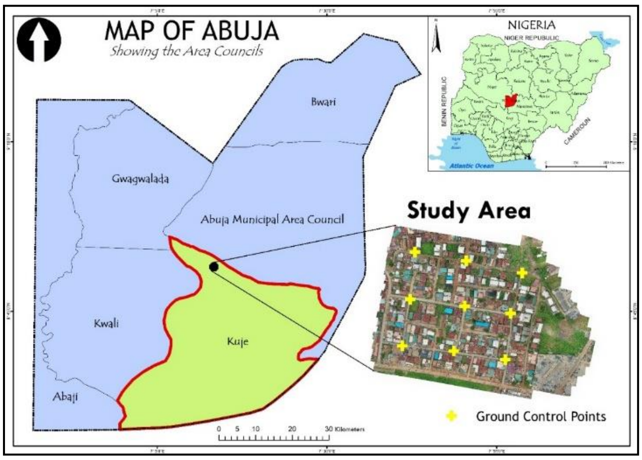

Figure 1. Map showing the location of the study area

2.2 Data acquisition and processing

The first step was to carry out a UAV flight of the study area and processing using the already established SfM method on the Pix4D Mapper software. The UAV flight was carried out in the year 2020. The flight path was predefined on the Dronedeploy software installed on the iPhone 7s device which was attached to the remote controller of the UAV. The degree of overlap maintained during the survey was 60% (forward) and 75% (side). A historical image for the year 2005 was also downloaded from Google Earth.

The two images (the 2020 and the 2005 images) were geometrically aligned to enhance comparison. The procedure was carried out using manually selected GCPs, where identifiable keypoints in both images were used to geometrically align the 2005 satellite image with the 2020 UAV image.

2.3 Image vectorization

The images were imported into ArcGIS software where the features in the area were converted into a series of points, lines and polygons by digitizing directly from the screen display on ArcMap. The main features vectorized in both images were the buildings (completed and uncompleted) and the plots (developed and undeveloped).

3. Results

The orthophoto generated from the Pix4Dmapper processing is shown in Fig. 2.

The orthophoto has a spatial resolution of 1.43 cm. A point-to-point validation done by the Pix4Dmapper software using 9 checkpoints showed an RMSE of 21.108mm, 25.347mm and 96.060mm in the x, y and z directions respectively. This shows that the orthophoto has high positional accuracy.

Digital maps were produced within the ArcMap environment, one for 2005 (see Fig. 3b) and the other for 2020 (see Fig. 3a).

The analysis of the changes in urban developments are shown in Table 1.

Figure 2. Orthophoto map of the study area – year 2020

Figure 3. (a) 2020 digitised map from the orthophoto (b) 2005 digitized map from the acquired Google Earth Historical Image

Table 1. Comparison between the maps

Class	Count - 2005	Count - 2020	Change
Completed buildings	185	313	128
Uncompleted buildings	15	7	-8
Total	200	320	120
Developed plots	182	234	+52
Undeveloped plots	68	16	-52
Total	250	250	-

4. Discussion

Several differences can easily be spotted in the distribution of features in both maps. The maps show the extent of undeveloped plots within the study area in green. At first glance, it can be observed that a lot of the undeveloped plots noticed in the 2005 map have now been developed.

In the year 2005, there were 200 buildings within the study area, 185 (92.5%) of which were already fully erected and 15 (7.5%) still under construction. The total number of buildings recorded in the year 2020 is 320, with 313 (97.81%) fully completed and 7 (2.19%) still under construction. As can be deduced from the table the period of study (2005 to 2020) has recorded an increase of 120 buildings. It is also observed from the map that all the buildings under construction in 2005 are now fully completed.

The study area was divided into 250 plots. In 2005, only 182 (72%) of the plots had been developed. The study period however witnessed the development of 52 more plots, bringing the total number of developed plots to 234 (93.60%).

5. Conclusion

This study conducted on a section of Kuje Area Council has shown that Unmanned Aerial Vehicles (UAVs) and SfM Photogrammetry can be effectively utilized for different purposes, such as urban change detection analysis and infrastructural planning and monitoring. The maps produced will facilitate a more informed decision-making process for various urban planning activities in the area.

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