International Research Journal of Nature Science and Technology (IRJNST) E-ISSN: 2581-9038

Volume: 03 Issue: 06 November to December 2021 www.scienceresearchjournals.org

Mapping of the University of Nigeria Enugu Campus using the Unmanned Aerial System

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ABSTRACT

Surveying, both theoretically and practically in the last few decades has witnessed tremendous developments both in techniques and instrumentation. This is evident in ways in which technologies evolve and are phased out, been replaced by the more recent ones. This emerging trend of events has kept survey professionals in developing countries like Nigeria on their toes in order to keep abreast with survey practices all over the world. Here, we demonstrate how one of these emerging trends can be deployed for surveying activity. In this paper, the Unmanned Aerial System (UAS) was applied for the Mapping of the University of Nigeria Enugu Campus. The procedure started with a careful reconnaissance of the entire Campus after which pre-flight activities such as choice of ground control points (GCP's), pre-marking of the GCP's, flight constants (e.g. flying height) selections, etc., were carried out. The Unmanned Aerial Vehicle (UAV) was utilized for the acquisition of data in an autonomous manner through the Drone Deploy application. The acquired data was transferred to Agisoft Met shape Professional application program which was used for further processing as well as stitching of the photographs to form a mosaic geo-referenced image of the Campus that can be exported to any appropriate mapping software. The mosaic was added into the ArcGIS 10.5 which was used for the map production and presentation. The DJI Phantom 4 Unmanned Aerial Vehicle with attached optical sensor was utilized for the data acquisition while the processing and presentation was done using the Agisoft and the ArcGIS application programs respectively. The map of the Campus as well as the Digital Elevation Model was produced. Conclusively, we believed that the UAS technology which has come to stay has a lot of benefits over Aerial Survey as it was previously practiced and Satellite based method of acquiring Imagery especially when the surveyed area is not global in size. The UAS presents a very convenient and somewhat cheaper alternative to aerial mapping especially when the area coverage is not too expensive. The team recommends that more researches need to be carried out on the area of using the UAS for topographic missions since the height obtained from GNSS which is the base positional technology for the UAS is ellipsoidal and not other metric. This is due to some of the unresolved uncertainties associated with our local geoid in Nigeria, though the elevation models generated for this study is through the concept of stereoscopic imaging.

Keyword: *Mapping, Unmanned Aerial System, Ground Control Points*

1.0 INTRODUCTION

The rapid developments in the field of Geoinformatics and Surveying have constantly changed the practice of the discipline in a tremendous way, new tools emerge now and then and are overtaken by even newer innovations and all these are due to man's unending quest to better understand, subdue and utilize the environment. Surveying practice has therefore moved from the conventional and classical methods to the Remote Sensing techniques making it possible to obtain valuable information about parts of the earth without the need of having any physical contact with the object or phenomenon been measured.

Early records of the use of Remote Sensing are dated to the 1840s when balloonists acquired pictures of the ground with the newly invented photo-camera. Perhaps the most novel platform is the famed pigeon fleet that operated as a novelty in Europe around the 1900s. Since then, Remote Sensing has been evolved with the emergence of various tools. Satellites are launched into space with various payloads/sensors for acquiring data that serves in various applications.

Photogrammetry which can be Terrestrial, Airborne or Space-borne depending on the location of the platform operates with energies in the visible region of the Electromagnetic Spectrum and has also been widely used in Surveying for the acquisition of data required for all forms of mapping activities. The Airborne or Aerial Photogrammetry; the most applied form of photogrammetry for Surveying applications has before now utilized the Manned Aircraft as the platform for data acquisition, that however is rapidly changing as the Unmanned Aerial System are increasingly finding relevance in the survey industry for photogrammetry.

2.0 LITERATURE REVIEW

The Unmanned Aerial System (UAS) (also referred to as Unmanned Aircraft System) is a system which comprises of the unmanned air vehicles and associated accessories and equipment that do not include an onboard pilot but fly autonomously and are remotely piloted (Gupta et al. 2013).Similarly, European Aviation Safety Agency (EASA) defines UAS as "An Unmanned Aircraft System (UAS) comprises individual system elements consisting of an "unmanned aircraft", the "control station" and any other system elements necessary to enable flight, i.e. "command and control link" and "launch and recovery elements". There may be multiple control stations, command & control links and launch and recovery elements within a UAS." (EASA 2009) The components of the UAS therefore include the Unmanned Aerial Vehicle (UAV) or the Aircraft, Controls Stations (also known as Ground Controls Stations (GCSs), the Data links (that is Communication peripheries), etc., (Fahlstrom and Gleason 2012). Austin (2010) shared a similar opinion when he stated that "An unmanned aircraft system is just that – a system. It must always be considered as such. The system comprises a number of sub-systems which include the aircraft (often referred to as a UAV or unmanned air vehicle), its payloads, the control station(s) (and, often, other remote stations), aircraft launch and recovery sub-systems where applicable, support sub-systems, communication sub-systems, transport sub-systems, etc." Each of these components forms a complicated system which comprises of several other components. For instance, the Air vehicle itself is made up of several components which include structures, aerodynamic elements (wings and control surfaces), propulsion and control systems, payloads, communication packages, and the launch and recovery subsystems (Fahlstrom and Gleason 2012).

An unmanned aerial vehicle has also been defined according to Dalamagkidis et. al. (2012) to "refer to a pilotless air-craft, a flying machine without an on-board human pilot or passengers." They emphasized that "unmanned" therefore means that there is absolutely no presence of a human who either directs or pilots the aircraft on-board.

Although the use of UAVs was driven primarily for military applications, it has however found relevance for civilian users for earth observation, reconnaissance and scientific collection of data (Watts et. al. 2012). Deployments of UAS for civilian/public users as well as other commercial applications are projected to be dominant in the near future (Dalamagkidis et. al. 2012).It should also be noted that the UAS currently have revolutionized warfare, and it has been forecasted that most of the manned military aircraft assignments will be undertaken by UAS in the near future(Fishpool 2010). The field of surveying and earth observation is not left out as Aerial Photogrammetry is one of the many applications of the UAV (Wolf and Dewitt, 2000)

The thought of a "flying machine" was initially conceived about 2500 years ago, in ancient Greece and China (Dalamagkidis et. al. 2012). However, the first practical unmanned airplane was in 1918, toward the end of World War I (Degaspari 2003).

Nowadays, UAV's has been greatly deployed to tackle challenges in diverse applications across several fields of learning /human endeavor because it is less expensive, safer and flies at a lower altitude. Photogrammetric techniques and emerging aerial technology has made it possible for UAV's to be utilized in generating Digital Elevation Model (DEM) (Arif et. al. 2018). This hitherto was only by deploying manned aircraft and specialized metric camera which come at a great cost (Udin and Ahmad 2014). Everaerts (2008) shared the same thought when he posits that UAVs have been a preferred choice for most people for Remote Sensing applications and this has been attributed to the cost of the mission, quick response and considerations for aircrew in hostile or dangerous environment. Therefore, UAV can be used to identify elevation in small areas with a limited project budget and time constraints (Arif et. al. 2018).

UAS has also been deployed for several Remote Sensing Earth Observation applications in Agriculture (McCabe et. al. 2016), Infrastructure (Fan and Saadeghvaziri, 2019), Geosciences (Niedzielski,2018), Archaeology (Çabuk, 2007), and Mapping (Everaerts, 2008), and has been predicted to be usable in the execution of surveying projects such as leveling, with less time expended, reduced cost and less manpower (Rahman et. al. 2017).

UAS has been utilized for airborne photogrammetry and is currently showing some advantages. Satellite based photogrammetry is weather dependent and expensive as very high resolution photogrammetric imaging satellites are operating mainly in the single image mode. To get stereo pairs, it has to be on demand. Radar Interferometry; though weather independent (even though rainfall poses a challenge), is time consuming and quite complex to elaborate. (Pulighe & Fava 2013). Since the classical field survey methods are economical only when the area of coverage is relatively small, aerial photogrammetry has proven to be an accurate and a powerful tool for generating surface model, and the extraction of high resolution DEMs through the means of automated image matching techniques(Fabris and Pesci, 2005). Very high-resolution aerial imagery are available currently for the modeling of more detailed earth surface processes (Jarvis et al., 2004; Marzolff and Poesen, 2009; Prokešová et al., 2010), especially in disciplines such as hydrology, pedology, geomorphology and landslide dynamics. In particular, historical aerial photographs acquired in Italian archives over the past 60 years [Fabris and Pesci, 2005; Fabris et al., 2011], as well as in other countries, represent an extensive stock of data that aids environmental studies, and used generally for planning purposes.

The methods and procedures of automatic DEM extraction and generation of orthophotos from digital stereo imagery is well known and properly documented (Rivera et al., 2005; Pieczonka et al., 2011].

Pulighe & Fava 2013 in their work titled “DEM Extraction from Archive Aerial Photos: Accuracy Assessment in Areas of Complex Topography” agreed that DEMs which are photo-based are very competitive, cheap and affordable, readily accessible, available and relatively precise, especially in the absence or inaccessibility of other expensive high-resolution data (e.g. LiDAR).

In photogrammetry, overlapping photographs are used to measure coordinates as well as determine elevations, and these overlapped photos are then utilized for the preparation of either Planimetric or Topographic maps at desired accuracy (Arif et al 2018). High density colored cloud of points can be generated from the high resolution photographs through the application of recent photogrammetry method based on Structure from Motion (SfM) algorithm and Multi View Stereo (MVS) that incorporates computer vision feature into the classical 3D photogrammetric technique (Caroti et al 2015)

The DJI Phantom 4 UAV is a multi-rotor UAV which utilizes the Vertical Takeoff and Landing Techniques and weighs about 1.4kg making it less susceptible to wind disturbance. Among other features that make the DJI Phantom 4 UAV an excellent channel for the capture of survey grade geospatial data, it is important to mention that the UAV has a 3-axis (pitch, roll, and yaw) stabilization gimbal feature, incorporates the GPS/GLONASS Satellite Positioning Systems, has an effective Operating Temperature Range of 32° to 104°F (0° to 40°C) and has a Max Service Ceiling Above Sea Level at 19685 feet (6000 m).

This gives the DJI Phantom 4 UAV an edge over several entertainment UAVs for survey related operations such mapping, DEM generation, etc. The application software that is linked with the UAV operations incorporates a Google Earth interface for easy reconnaissance, site selections, review of flight plans and marking out of area extents.

Arif et. al. 2018 in their study using the DJI Phantom 3 asserted that the UAV system can be utilized to generate DEM with accuracy levels at the sub-meter. They concluded by saying that for a limited timeframe and over a relatively small area, the UAV is applicable with the recommendation that UAV flights for DEM generation should not be flown at an altitude higher than 110m.

The UAV can be operated both autonomously and manually with a resolution of about 5cm/pixel achievable at 100m altitude. GCPs can be pre-marked prior to flight to improve accuracy of the final product; a method adopted for the study at hand.

Agisoft Metashape is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images. Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated.

Maps have been described as visual expressions of parts or portions of the earth surface and mapping surveys are conducted by one of the two basic methods of Aerial (Photogrammetry) or ground (field) methods, most times however, both methods are combined (Ghilani and Wolf, 2012).
Mapping with Remote Sensing/aerial methods most times involves the use of GCPs which must have been previously coordinated using conventional ground survey techniques or the Global Navigation Satellite System (GNSS) method.
Maps come in various scales and can either be hardcopy; produced in several base materials and also in softcopies in digital formats on-screen.
In this project which combines both methods as stated above (as GCPs were products of field methods), we demonstrate the efficiency of the UAS as a veritable tool for data acquisition for large scale and semi small scale mapping operations. UAVs have been accredited with some advantages over conventional satellite and airborne remote sensing data acquisition platforms, such as space based satellite system and manned aircraft, because of low costs of operations, high operational flexibility and high spatial resolution of imagery (Matese et. al. 2015), especially when the area coverage is not global. The data required for the mapping of the Enugu Campus of the University of Nigeria was therefore acquired using the UAS technology. This was then integrated into a Geographic Information System (GIS) application for map compilation and production, therefore proving that UAS; used for several civilian and commercial applications, can also be deployed in data acquisition required in a GIS for mapping purposes, proving very essential in the practice of Geoinformatics and Surveying.

3.0 MATERIALS AND METHODS

At this section, we will discuss the step by step procedure for the acquisition of data using the UAS technology as well as the materials required for this project. This covers from first reconnaissance to the final products.

The Materials used include

Hardware

- DJI Phantom 4 UAV
- Garmin 72H Handheld GPS Receiver
- Markers for Ground Control Points
- HP laptop with the specifications: Intel(R) core i5 CPU@ 1.70GHz 8GB RAM

Software

- Agisoft Meta shape Professional
- Drone Deploy
- ArcGIS
- Microsoft Office Suite

Method

Planning has been defined by wiktionary.org as the act of formulating of a course of action, or drawing up plans. It is an indispensible component in every human venture or activity that is expected to succeed. Surveying and mapping of earth's resources is not exempted as every survey operation starts with a form of planning.

In the mapping of the University Campus using the unmanned Aerial System, Important components noted during planning stage include choice of control points, appropriate flying details (Flying Height, Side-Lap, End-Lap, etc.), number of photographs that will cover the entire mission, memory requirements, weather forecast for proposed day of flight, etc.

Before the flight mission is planned, the Hand-Held GPS equipment was used to determine the approximate coordinates of the extents of the campus, this was plotted into the Agisoft application which is interfaced with the Google Earth application. The following procedures were adopted for the project and will be discussed under three headings as Data Acquisition, Data Processing and Presentation:

4.0 DATA ACQUISITION

1. Reconnaissance: This is accomplished by taking a general overview of the study area in a site visit, taking notes of the terrain pattern, the extents and the choice of suitable locations for Ground Control Points (GCPs). The extent of the University is updated in the Drone Deploy application.

2. Planning: The application "Drone Deploy" is utilized for the flight planning. To plan the flight, the app has an integrated Google Earth interface which serves for the reconnaissance, viewing the Campus and also to map out the area required. From the app, we set the flying altitude above ground level(AGL) accompanied with the settings of the End lap and Side lap of the image (75% side lap and 65% end lap). The overlaps are very important as the concept of stereoscopic viewing and photogrammetric heightening is the basic theory for obtaining elevations by optical means. The app takes all this in consideration and generates automatically the flight plan that would accomplish it in the most efficient way. Once all this is set, the application gives the total number of photographs to be taken which gives an idea of the memory capacity required to complete the mission. This is important as data acquired are saved on a memory card attached to the UAV.

3) The coordinates and information about the existing controls were acquired from records; the coordinates for the selected Ground Control Points were extracted and checked. Other forms of Insitu checks were also done to ascertain that the control monuments are still as emplaced. These checks are very important as it tells on the final accuracy of the mapping results.

4) Ground Control Points were then pre-marked prior to the flight for the data capture. See figure 1. The markers are placed such that they are flattened out as much as possible and that the survey point over the monument coincides exactly with the center of the marker. This of course improves the reliability of the geo referencing operations and the general accuracy of the survey. To avoid the effect of wind on the targets, weights are placed at the edges of the Target marker.

5) UAV Flight: After the flight has been planned, flying details agreed on, and control points selected and marked, the next step was to carry out the UAV flight. This is simply done by setting up the UAV through the Drone Deploy application and activated to carry out the flight mission. The flight is done autonomously as the UAV follows the pre-determined flight path. The role of the Drone Pilot at this point is mainly supervisory; to ensure that the flight is going as planned, or call back the UAV in the case of an abnormal event or if there's a need to change the battery. This is possible because the UAV remains in communication with the control station throughout the flight; this is achieved through a radio link between both systems.

Figure 1: (a) Marking of Control Point (b) Control Point opposite Anatomy Department

As the flight mission progresses, the Drone Pilot also through the display at the control station, have a view of the photographs on read-only mode because the data is saved on the memory stick that is onboard the UAV. When there's a need to change the battery prior to the end of the data acquisition mission, the UAV is called back, battery changed and sent back to the flight. When this is done, it automatically went to where the captured stopped before it was called back and continue acquiring images. The UAV returns to take off base at the end of data acquisition.

6) The overlapping photographs are transferred to the computer either through USB cable connection or by removing the memory card and slotting it in the computer's card reader. See an example of one of the photographs in figure 2.

Figure 2: An Aerial photograph

5.0 DATA PROCESSING

The data processing procedure is a highly automated process as it happens mostly over the application software (Agisoft Metashape Professional) chosen for this study. Agisoft Metashape is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales. Some features of this photogrammetry software is that it differentiates between various objects such as buildings and trees that allow filtering, the Metashape improves the processing time and quality of captures on previous iterations in order to enhance its algorithms and machine learning and by using a multitude of export formats, Metashape products can be easily transmitted into external instruments. Also, Metashape gives you an ability to customize Python scripts to maintain the processing workflow.

The aim of this stage of the processing is to produce an ortho-rectified georeferenced imagery which is a mosaic of individual overlapping photographs as well as the Digital Elevation Model (DEM). All the relevant procedures and orientations are carried out autonomously in the application.

The processing carried out in the Agisoft application consists of the following main steps. The first step is to load the photos. This is achieved by launching the application, clicking workflow on the task bar which brings a drop down menu and clicking on “Add photos”. The added images are inspected and unnecessary images are removed. The next step is to align the photographs. The Metashape at this stage searches for common points on photographs and matches them, as well as it finds the position of the camera for each picture and refines camera calibration parameters. As a result, a sparse point cloud and a set of camera positions are formed. Several other steps include the building of the dense point cloud, building of the mesh, generating the texture and building the tiled model. All this procedures are done automatically by the application at the click of a button.

When all these have been done, we proceeded to building the Digital Elevation Model (DEM) as well as building the Orthomosaic. The Orthomosaic and DEM were saved as a .Tiff file or as a .GeoTiff which saves the coordinates and the map projection to it. The image and DEM is now ready to be included in any mapping software.

6.0 DATA PRESENTATION

There are several mapping and drafting software which can be used for the final production of the map, the procedures for the most of these applications are similar given that an Orthorectified georeferenced image as well as the DEM of the area under study is available.

The ArcGIS 10.8 application package was used in this project. Similar to other mapping software, the first step is to launch the application after which the Orthomosaic is added through the “Add data” interface.

The Data View space used for the map preparation adopts the coordinate system of the incoming data since none was set in the beginning. After the data (the Mosaic) has been successfully added, shapefiles are created for all features of interest through the Arc Catalogue, this was followed by a process called digitizing of features which is simply converting the important features in the study area into a map using the three object primitives i.e. point, line and polygon in their respective shapefiles.

The database of each feature is also populated with the required basic attributes about the features so that information about any feature can be easily extracted.

When the objects of interest have been fully digitized, the Layout View is toggled on, scale is set and other cartographic finishing such as Title, Scale, Legend, and North Arrow etc. are added. Hard prints can therefore be acquired if desired. See figure 3.

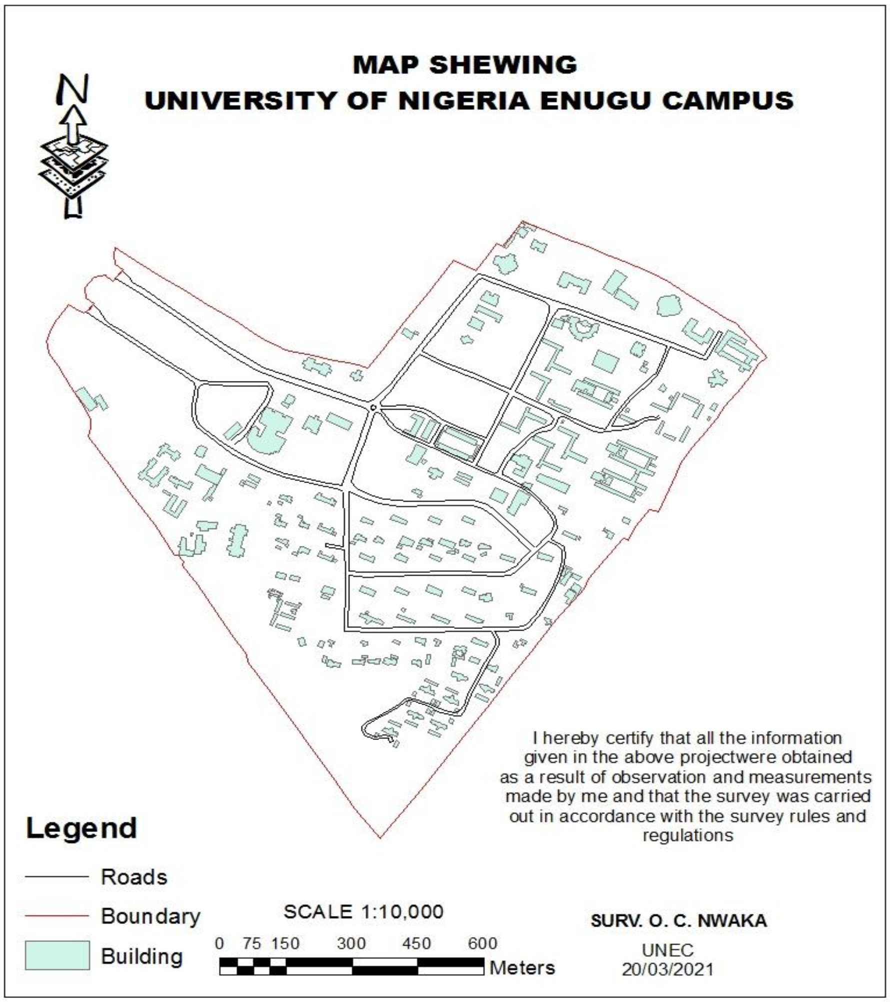
From the DEM generated during the data processing, the contour of the area was also generated.

7.0 DISCUSSIONS

The UAV technology has been shown to be capable of been deployed for the acquisition of data for mapping purposes. Its techniques are fast, efficient and relatively cost effective and with the right GCPs, its accuracy can be very competitive. It is not affected by cloud coverings like the Satellite System as it can be deployed at varying altitudes even below the cloud formations. The technology presents very wonderful potential for geospatial data acquisition and can come in very handy and readily available for all mapping requirements especially when the area of interest is not globally extensive in size. It is also an excellent tool for disaster management and real time monitoring as required in forest fires, flooding, etc. The UAS technology can also be utilized for monitoring in agriculture, construction (especially high rise) as well as surveillance.

8.0 CONCLUSION AND RECOMMENDATIONS

The mapping of the University campus was carried out successfully in a timely fashion through the deployment of UAS technology. The UAS presents a lot of possibilities for data acquisition for all geospatial needs. Given the appropriate Ground Control Points, the UAS can compete favorably with other Geospatial Data Acquisition systems in terms of accuracy, and it is relatively cheaper compared to the Satellite platforms especially for a small area.



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