UPDATING OF UNIVERSITY OF BENIN UGBOWO CAMPUS MAP USING UNMANNED AERIAL VEHICLE

BY

OBOH PRINCESS MAUREEN
ENV1906062

DEPARTMENT OF GEOMATICS
UNIVERSITY OF BENIN
BENIN CITY, NIGERIA
P.M.B 1154

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF SCIENCES {BSCGEM - B.SC. GEOMATICS} DEGREE, IN THE FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA

FEBRUARY, 2025

UPDATING OF UNIVERSITY OF BENIN UGBOWO CAMPUS MAP USING UNMANNED AERIAL VEHICLE

A PROJECT SUBMITTED

BY

OBOH PRINCESS MAUREEN
ENV1906062

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
AWARD OF A BACHELOR OF SCIENCES {BSCGEM - B.SC. GEOMATICS} DEGREE,
IN THE FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF BENIN,
BENIN CITY, EDO STATE, NIGERIA.

FEBRUARY, 2025

CERTIFICATION

This is to certify that this project was carried out by **OBOH PRINCESS MAUREEN** with Matriculation Number: **ENV1906062** of the Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria.

SUPERVISOR Date

Dr. Nwodo Geoffrey

HEAD OF DEPARTMENT Date

Surv. Dr. S.O. Oladosu

EXTERNAL EXAMINER Date

DEDICATION

I sincerely with a grateful heart dedicate this project to God Almighty for His Grace upon my life and to my parents (Mr David Oboh & Mrs Magdalene Oboh), my beloved siblings and friends for their support in all ramifications. May God continue to bless and keep you all, Amen.

ACKNOWLEDGEMENT

I offer thanksgiving and gratitude to God Almighty for His endless grace and mercy bestowed upon my life. I also want to appreciate my lovely parents, Mr David Oboh & Mrs Magdalene Oboh for their endless support spiritually, morally and financially that has helped me thus far in life. May God reward and bless you for your tireless efforts, Amen.

My sincere gratitude also goes to my supervisor Dr. Nwodo Geoffrey for his constructive suggestions, criticisms, corrections and encouragement throughout this project.

I want to thank the staff and management of the Department of Geomatics, the University of Benin for their advice and guidance; Engr. Surv. Prof. Raphael Ehigiator (Dean), Surv. Dr. Nwodo Geoffrey, Surv. Dr. S. O. Oladosu (HOD), Surv. Mercy Ekun, Engr. Mabel, Surv. Ojo Peter, Surv. Dr. Odunmosu, Surv. Tijani, and other staff members of the department. May God bless you all. Amen.

ABSTRACT

Accurate topographic mapping is vital for effective land-use planning, infrastructure development, and environmental monitoring. The integration of advanced remote sensing techniques, particularly the use of Unmanned Aerial Vehicles (UAVs), is highly advantageous for creating efficient and precise terrain models. The importance of high-resolution topographic data cannot be overstated, as it is integral to engineering applications and geospatial analysis. This study aims to produce a detailed topographic map of the University of Benin's Ugbowo Campus, located along the Benin-Lagos Expressway in Benin City, Nigeria, utilizing the DJI Phantom 4 RTK drone.

The methodology employed key topographic parameters, including elevation, slope, aspect, and terrain variation, to create a high-accuracy Digital Elevation Model (DEM). A UAV was operated at an altitude of 120 meters in a 3D flight mode, capturing high-resolution aerial imagery. To ensure precise geo-referencing of the orthophoto, Real-time Kinematic (RTK) GPS technology was utilized with an RTK-enabled drone, thus eliminating the need for Ground Control Points (GCPs). The acquired imagery was then processed to produce an orthophoto, which served as the basis for deriving the DEM, and contour lines were extracted at 5-meter intervals to illustrate elevation variations.

The accuracy of the model was assessed through a positional accuracy analysis, revealing that the generated topographic data achieved a remarkable precision of less than 5 cm. This outcome underscores the high accuracy of UAV-based mapping techniques. The resulting topographic map provides a comprehensive representation of the terrain, facilitating improved decision-making in urban planning, construction, and geospatial analysis.

In conclusion, this research showcases the effectiveness of UAV photogrammetry, particularly through the integration of RTK technology, in producing precise topographic maps. It highlights the promise of UAV-based surveys as a cost-effective and efficient alternative to traditional surveying methods, especially in challenging or inaccessible terrain. By achieving exceptional positional accuracy, these techniques not only enhance the quality of the collected data but also significantly contribute to improved decision-making across various domains, including urban planning and construction.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Topographical maps are indispensable for surveyors, engineers, architects, and planners alike. They provide an in-depth analysis of the surrounding terrain and invaluable insights into various land features. (Mavrou 2024) ,

Topographical mapping is the process of creating a detailed and accurate map of the surface features of a landscape, including elevation changes, natural and man-made structures, and other topographic details. Topographical maps are essential for a variety of applications, including urban planning, land use management, environmental monitoring, and engineering projects.

Traditionally, topographical mapping involved surveying the terrain using a combination of ground-based instruments such as total stations and GPS receivers. However, advancements in technology have made it possible to conduct topographical mapping using unmanned aerial vehicles (UAVs), also known as drones.

UAVs are equipped with high-resolution cameras and other sensors that can capture detailed images of the landscape from above. These images can be processed using photogrammetry software to create 3D models and maps of the terrain with a high level of accuracy.

One of the key advantages of using UAVs for topographical mapping is their ability to access hard-to-reach or hazardous terrain, such as steep slopes, dense forests, or areas affected by natural disasters. UAVs can also cover large areas quickly and cost-effectively, making them an ideal tool for mapping expansive landscapes.

In addition, UAVs can capture data at different times of day and under different weather conditions, allowing for the creation of detailed and dynamic maps that can be used for monitoring changes in the landscape over time.

In a study by James et al. (2015), UAVs were utilized for topographical mapping in a densely vegetated area in Utah. The researchers found that UAVs provided high-resolution imagery that could be used to create detailed topographical maps with a level of accuracy comparable to traditional surveying methods. The study highlighted the potential of UAVs for mapping in challenging environments and the benefits of using UAVs for topographical mapping.

Another study by Khelifa et al. (2017) focused on using UAVs for topographical mapping in a coastal area in Algeria. The researchers found that UAVs were able to capture detailed imagery of the area, including the coastline and surrounding terrain. The study demonstrated the effectiveness of UAVs for mapping coastal areas and their potential for monitoring changes in the landscape over time.

In recent years, there has been a growing body of research on the use of UAVs for topographical mapping. For example, a study by Colomina and Molina (2014) evaluated the use of UAVs equipped with different sensors for topographical mapping and concluded that UAVs are a cost-effective and efficient tool for collecting high-resolution terrain data.

Similarly, a study by Lin et al. (2018) compared the accuracy of UAV-based topographical mapping with traditional ground surveying methods and found that UAVs were capable of producing maps with comparable or even higher levels of accuracy.

Overall, the use of UAVs for topographical mapping has revolutionized the field by providing a fast, accurate, and cost-effective method for creating detailed and up-to-date maps of the terrain.

This technology is becoming increasingly popular in a wide range of applications, from environmental conservation to infrastructure development.

This study examines the accuracy and efficiency of a topographic survey carried out using a combination of Differential GPS (DGPS) equipment and a consumer-grade Unmanned Aerial Vehicle (UAV). The research is centered on the mapping of Ubgowo Campus aiming to create a detailed topographical map of the study area.

1.2 Statement of the problem

The existing map of the Ugbowo campus, has become outdated due to the rapid pace of infrastructural development. Utilizing an Unmanned Aerial Vehicle (UAV) system offers an efficient solution for producing an updated topographic map of the study area. This approach provides a cost-effective and timely method to update the map, ensuring accuracy and reflecting recent changes in the landscape. UAV technology enables high-resolution aerial imagery and precise elevation data, making it a practical tool for generating up-to-date and detailed topographic maps, which are essential for campus planning and development.

1.3 Aim and Objectives

The aim of this project is to conduct topographic mapping of a of Ugbowo campus, using an Unmanned Aerial Vehicle (Drone) at 120m flight altitude to capture accurate and higher resolution spatial data for detailed analysis and terrain modeling. The objectives of this project are to:

1. Develop a flight plan for image acquisition.

2. Capture image data using the DJI Phantom 4 RTK Drone

3. Process the images using the acquired software.

4. Generate Orthophoto, Digital elevation model, Point cloud, and Contour using the required software.

1.4 Scope and Limitation of the Study

This research endeavors to utilize drone technology for topographic mapping of Ugbowo campus at the University of Benin, offering an efficient and comprehensive method for capturing the campus terrain and infrastructure. The scope of this project is to conduct extensive aerial data collection to produce Digital Terrain Models (DTMs), contour maps, and 3D models. It will cover all major land features such as buildings, roads, vegetation, and drainage systems, with a focus on an accurate representation of the terrain. These outputs will be instrumental for campus planning, infrastructure assessment, and environmental management. UAVs provide higher-resolution imagery and precise elevation data, facilitating analysis of land use, drainage patterns, and elevation changes across the campus.

However, it is important to recognize the possible limitations of drones. Weather conditions such as rain or wind can disrupt flight operations, and flight restrictions are common in urban areas. UAV battery life limits flight duration, potentially requiring multiple flights for complete coverage. Vertical obstructions like buildings and trees may lead to incomplete data capture in certain areas. Additionally, large volumes of data require significant processing time, and while UAVs provide high accuracy, they may not always match the precision of traditional ground survey methods. The cost of equipment, expertise, and data privacy concerns also add to the limitations. Despite these challenges, UAVs remain a valuable tool for efficient and detailed topographic mapping.

1.5 Justification of the Study

The basis for the study of topographic mapping using UAVs of the Ugbowo campus at the University of Benin, is on acquiring accurate and comprehensive data essential for informed planning and development. Topographic mapping is vital for comprehending the campus's terrain, identifying land use patterns, and evaluating environmental features. This information is indispensable for efficient resource management and infrastructure development.

Utilizing drone technology in this study enhances the mapping process by providing high-resolution imagery and detailed topographic information quickly and efficiently. This approach minimizes costs and time compared to traditional surveying methods, allowing for timely data availability. Moreover, the precise topographic data generated will support informed decision-making, helping the university align its development strategies with sustainability goals.

In addition to addressing immediate mapping needs, this study creates opportunities for students and faculty to engage with advanced technology, fostering innovation and enriching the educational experience. Overall, the study not only aims to produce accurate topographic maps of the campus but also contributes to the university's broader objectives of sustainable development and effective land management.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This research report's literature review covered numerous key areas before diving into the dissertation topic Topographic Mapping Using Unmanned Aerial Vehicles . The key aspects include;

- The definition, advancement, and uses of Unmanned Aerial Vehicles ,
- Topographic UAV applications in the realm of surveying,
- The accuracy with which UAVs can conduct topographic land surveys

2.1 TOPOGRAPHICAL MAPPING

From a very early period, humans have attempted to graphically depict the earth's surface for the benefit of their fellow humans, aware that no written or spoken description can convey topographic details with the vividness and clarity of a map. (Evans & Frye, 2009). These first maps represented landscapes long before the application of scientific methods to cartography in the sixteenth century when the concept of sketching to a fixed scale revolutionized topographical mapping (Harvey, 1980: 14).

Historical maps are crucial for topographic mapping as they offer a reference to previous landscapes and infrastructure. No discussion of historical maps would be complete without discussing the largest early map of the world, created by Urbano Monte in 1587. The completed map has a circumference of a little over ten feet, making it one of the biggest, if not the biggest, globe maps created in the sixteenth century. Monte created his map with the intention of creating a worldwide scientific planisphere, as well as a geographical tool that would also display factors such as climate, customs, day length, and distances within areas. The significance of historical maps as primary resources is underscored by Monte's map. (Map Collection of David Rumsey, Monte, 1587). In the realm of cartography today, topographic maps hold a special and authoritative place. This authority comes from the fact that map symbols are created under the direction of governmental institutions, such as national mapping organizations and the military, in addition to the seeming scientific accuracy with which these map symbols match real-world features.

Surveying and mapping national territory is a vital responsibility for national mapping agencies, many of which are governmental. Wikipedia (National Mapping Agency, 2008) In order to serve a variety of applications, such as land management and environmental monitoring, they produce and maintain geospatial data, such as maps and geodetic networks. Wikipedia (National Mapping Agency, 2008) By creating precise cadastral maps for land registration and dispute settlement, NMAs are essential to land administration. (Halim and others, 2018) By offering geospatial frameworks and data, they also support economic growth, disaster relief, and spatial planning. As of 2019, Oksanen et al. A lot of NMAs are changing to include more comprehensive geospatial data management. Wikipedia (National Mapping Agency, 2008).

A consistent and thorough visual depiction of the Earth's surface is offered by topographic map series. They incorporate both natural and man-made elements, such as forests, rivers, roads, and buildings, and show the exact terrain characteristics using contour lines to show elevation. (Map of the topography, Wikipedia, 2002) (Mapping Topographically (2013) Accurate measurements of areas and distances are made possible by these standardized map series, which guarantee uniform scales and constant geographic coverage. (Wikipedia, 2010; Map series) (Lake &

Associates, 2000) Urban planning projects, engineering, environmental management, navigation, and outdoor leisure are just a few of the many uses for them. (2010) Minister et al. (1931, Jones) With the advancement of Geographic Information Systems (GIS), topographical mapping has undergone a substantial transformation that has enhanced the techniques for gathering, analyzing, and displaying spatial data. Historically, the process of creating topographical maps involved physical labor-intensive ground surveys that were both time-consuming and extremely inaccurate. GIS, on the other hand, has streamlined the process and added accuracy, making it possible to produce maps more quickly and in greater depth. It is now simpler to examine and comprehend geographic features because of GIS technology, which integrates several layers of spatial data, such as infrastructure, water features, and elevation, into a single map. In domains including infrastructure construction, environmental management, and urban planning, this has proven very advantageous (Longley et al., 2015).

By encouraging the digitization of traditional maps and investing in cutting-edge technologies like satellite imaging and UAVs (Unmanned Aerial Vehicles) for data collection, National Mapping and Cadastral agencies have been instrumental in the expansion of GIS in topographical mapping. National standards for GIS data have been set by organizations like the Office of the Surveyor General in Nigeria, the United States Geological Survey (USGS), and the Ordnance Survey in the United Kingdom (Williamson et al., 2010). These standards guarantee accuracy and uniformity for a variety of applications. Additionally, by digitizing their cartographic collections, these organizations have made it possible to transform outdated paper maps into digital formats that work with contemporary GIS systems.

One of the most notable advances spearheaded by these organizations is the creation of National Geographic Data Infrastructures (NSDI), which provide a framework for the collecting, distribution, and management of geographical data across the public and private sectors. NSDI projects have increased access to geographic data and boosted collaboration across sectors, such as environmental management, disaster preparedness, and transportation planning (Rajabifard et al., 2006). Many national mapping agencies have made GIS data public through open data rules, fostering innovation and widespread use of geospatial technologies.

Furthermore, these organizations have made investments in capacity-building initiatives to teach professionals how to utilize GIS and more sophisticated spatial technologies like 3D visualization and Digital Terrain Models (DTMs). Because of this, topographical maps are now more precise, comprehensive, and able to accommodate intricate analyses—all of which are essential for making well-informed decisions in modern society (Goodchild, 2007).

Before the early 2000s, topographic maps were the most widely used source of comprehensive geographic data. But with the rise of web map servers, like Apple Maps, Bing, and Google Maps, as well as the growth of Open Street Map (OSM), the traditional dominance of National Mapping and Cadastral Agencies (NMCAs) has been challenged. OSM, which started as a user-generated platform, has now become a major international mapping resource, providing an alternative to the authoritative mapping products previously offered only by NMCAs.

Over time, the dynamic between OSM and NMCAs has evolved from initially being perceived as competitive. OSM is now seen by many NMCAs as a complementary tool, and the two frequently work together. National topographic maps now have better accuracy and richness as a result of the NMCAs' integration of OSM's crowd-sourced data, and OSM gains from the

NMCAs' official and more dependable datasets. In the private sector, businesses like Apple and Google continue to use geospatial data from NMCAs; they frequently buy national mapping products as a base and then modify them to meet their unique requirements. However, this interchange is largely one-directional, as private corporations generally update and modify the maps themselves after the first acquisition, without relying further on NMCA updates.

2.2 TOPOGRAPHICAL MAPS

Topographical maps are a significant resource for a variety of scientific and practical purposes, including examining the natural environment and planning infrastructure projects (Minster et al., 2010). These maps show precise graphic depictions of the Earth's surface, including hills, valleys, rivers, and the relative heights of various locations. Jones, 1931.

One important aspect of topographical maps is their scale, which represents the ratio of distances on the map to the actual distances on the ground. High-resolution topographical maps, often created using advanced technology such as the Shuttle Radar Topography Mission, can offer highly detailed and precise representations of the Earth's surface, vividly displaying features such as buildings, roads, and vegetation.

Topographic maps serve as general-purpose maps and are not specifically tailored for designing infrastructure such as roads or land reclamation projects. However, they offer essential baseline information for such endeavors by providing a comprehensive view of the terrain. The effectiveness of a topographic map should be assessed based on how well it serves its broad-purpose functions. During topographic surveys, geodetic determination is limited to key control points, with approximately one such point per 100 square miles for maps at a one-mile-to-oneinch scale. Similarly, elevation control is established using spirit-level benchmarks, typically at an average of one benchmark for every five square miles.

2.2.1 FEATURES DISPLAYED ON TOPOGRAPHIC MAPS

The topographic maps showcase various features that can be grouped into three main categories:

1. Hydrography, encompassing water features like ponds, streams, and lakes.

2. Hypsography, depicting the surface relief forms such as hills, valleys, and plains.

3. Man-made features such towns, highways, and cities are depicted as black cultural features, relief in brown, and hydrography in blue. Generally, green indicates places that are wooded. The primary goal of a topographic survey should be the creation of a topographic map; time and funds should not be squandered on exact monument construction, boundary demarcation, or benchmark establishment beyond what is required for field data collection. Property surveys are responsible for placing boundary markers; geodetic surveys concentrate on key reference points. Topographic surveys are responsible for identifying unmarked stations for mapping purposes.

2.2.2 ACCURACY LEVEL IN TOPOGRAPHIC MAPPING

It is naturally challenging to set a standard for the precision and degree of information needed in topographical mapping. The level of accuracy required of a topographer frequently depends on how the map will be used and the particulars of the area being mapped. Certain topographical maps, which are essentially sketches with little mathematical control, may fulfill a number of useful purposes, but others require a higher level of precision and detail.

Although maps can be created at the same scale, their level of representation might differ greatly. This implies that two maps of the same region may have quite different topographic detail and accuracy even though they have the same scale. Therefore, a highly controlled and meticulously created map may be more beneficial for specialized applications, while a less precise sketch may be adequate for more general uses.

To account for this unpredictability, topographers need clear instructions on the level of precision and detail needed for their work. Unlike traditional surveyors, topographers often have to use their own judgement or specific guidelines to determine the time and resources required to achieve the necessary accuracy and detail. The specific purposes of the map and the level of detail required, which can vary greatly between projects, influence this decision.

Clear instructions that outline the effects of contour intervals and scale should help topographers comprehend how these variables affect the utility of the map. Moreover, these protocols must cover technical aspects of the mapping procedure customized to the particular circumstances of the area under survey.

Topographers use a variety of surveying tools and techniques, each with its own set of documentation and procedures. But the best course of action frequently only becomes clear after a careful assessment of the terrain, taking into account its unique features. In order to guarantee the final map's accuracy and applicability, the skilled topographer must modify their techniques and make sure it satisfies the requirements for the purpose for which it is meant. In conclusion, the goal of the map, the features of the terrain, and the topographer's experience all influence how accurate a topographical map is, so precise instructions and flexible approaches are crucial for producing accurate maps.

2.2.3 BENEFITS OF TOPOGRAPHICAL MAPPING

- Provides an in-depth understanding of topographical characteristics to aid in land-use planning.
- Assists architects and engineers in creating safe infrastructure.
- Identifies critical habitats and assesses environmental impacts to support conservation efforts.
- Assists in the discovery of water and mineral resources.
- Facilitates resource deployment, evacuation planning, and disaster management

2.3 THE DEFINITION OF UNMANNED AERIAL VEHICLE

Unmanned aerial vehicles, also known as drones, are aircraft that are controlled remotely without the requirement for a human operator to be physically present within the vehicle. This can be done by an automated flight plan or by a human pilot on the ground (Torre et al., 2016).

2.3.1 THE EVOLUTION OF UNMANNED AERIAL VEHICLE

The evolution of unmanned aerial vehicles, also known as drones, has had a significant impact on various industries and applications, including aerial photography, military operations, environmental monitoring, and disaster relief. Drones were initially developed for military purposes in the mid-1800s, and countries began to explore their potential for carrying out missions and surveillance without risking human lives (Torre et al., 2016). Since the early 2010s, with the introduction of consumer drones by companies like DJI, advancements in communication, battery technology, and miniaturization have made it feasible for drones to be used for non-military purposes, opening up a wide range of possibilities across several sectors.

Unmanned aerial vehicles are a great tool for exploration, surveying, and emergency response because of their versatility and ability to cover a large area without physically touching the ground. The civilian use of drones has expanded to include weather monitoring, urban planning and management, search and rescue, and firefighting. (Et al., Shahmoradi, 2020). Moreover, drones' smooth integration into the larger Internet of Things ecosystem is a result of the rapid advancement of technology in their capabilities and the increasing need for creative solutions. These drones can be outfitted with appropriate communication devices to provide an extensive array of benefits.

2.3.2 DRONE MAPPING

Drone mapping is the process of employing drones to take aerial photos of the ground and then process those photos to create useful maps or models. A single, continuous image or 3-D model is created by stitching together overlapping photographs taken from various angles, a process known as photogrammetry, which forms the basis of this technology. This technology generates accurate 2D maps and 3D models of the Earth's surface. Specialized software converts overlapping photographs from various angles into georeferenced maps, Digital Surface Models (DSMs), and 3D point clouds.

The accuracy of drone mapping is influenced by several key factors, including the quality of the drone's Global Navigation Satellite System (GNSS), the resolution of its camera, flight altitude, and environmental conditions. Drones equipped with high-precision Real-Time Kinematic (RTK) GNSS systems can achieve positional accuracy within a few centimeters, eliminating the need for Ground Control Points (GCPs). RTK technology enhances accuracy by providing real-time corrections from a base station or network, effectively minimizing errors caused by satellite signal delays and atmospheric conditions.

In applications that require high precision, such as engineering and construction surveys, RTK drones deliver accuracy levels of approximately 2–5 centimeters, even without the use of Ground Control Points (GCPs). In contrast, standard drones that do not utilize RTK technology typically achieve accuracy levels ranging from 1 to 3 meters, making them more suitable for less demanding tasks like site monitoring or agricultural applications.

Various factors contribute to accuracy in data collection, with flight altitude playing a significant role—lower altitudes typically yield more detailed data. Furthermore, greater image overlap enhances the accuracy of 3D models. Environmental conditions, such as lighting and wind, can also impact image quality and positional accuracy. Therefore, careful flight planning and thorough data processing are vital to achieving consistent and high-accuracy results.

2.3.3 UNMANNED AERIAL VEHICLES MAPPING AREAS

Drones are being utilized for mapping and surveying in the following areas:

- Topography
- Urban Planning and Development
- Forestry Management
- Coastal and Shoreline Mapping
- Utilities and Power Line Inspections

2.3.4 APPLICATION OF UNMANNED AERIAL VEHICLE IN THE SURVEYING SECTOR

Here are some applications of UAV in the surveying industry

1.**Aerial Mapping and Photogrammetry**: High-resolution aerial photos are taken by UAVs and processed to provide Digital Elevation Models (DEMs), 3D models, and detailed maps for a range of surveying applications.

2. **Topographic Surveys**: By gathering photos from various angles and processing them to create topographic maps for building, land development, and environmental research, UAVs give precise topographical data.

3. **Infrastructure Inspection**: Roads, bridges, electricity lines, and pipelines are among the infrastructure types that UAVs are employed to inspect. They offer a quicker and safer substitute for conventional inspection techniques while producing excellent photos or videos that can be used for structural evaluation.

4. **LiDAR Mapping**: Extremely precise three-dimensional (3D) representations of the Earth's surface are produced by UAVs fitted with LiDAR (Light Detection and Ranging) sensors. LiDAR technology is very helpful in densely vegetated places because it can map the landscape beneath trees by penetrating the canopy. Digital terrain models (DTMs), flood modeling, forestry, and infrastructure planning are all done with LiDAR mapping.

5. **Volumetric Calculations**By creating 3D models, UAVs help surveyors calculate the volume of materials in stockpiles, quarries, or construction sites. Compared to traditional ground-based methods, this technology is safer, faster, and more efficient..

6. Cadastral Mapping: UAVs equipped with high-precision GNSS and imaging systems can efficiently and accurately capture data. This capability aids in updating cadastral records and land registration systems. Cadastral mapping involves the process of identifying and documenting property boundaries for land ownership. Consequently, UAVs are increasingly utilized in cadastral surveys to map properties and land boundaries.

2.3.5 ADVANCEMENT OF DRONES IN TOPOGRAPHIC MAPPING

Rapid improvements in drone technology have fundamentally altered the terrain of modern surveying and mapping, causing a paradigm shift in the discipline of topographic mapping. These aerial vehicles, known as Unmanned Aerial Vehicles, have emerged as a versatile and cost-effective method for acquiring high-resolution aerial imagery, which can then be used to generate precise Digital Elevation Models and other valuable geospatial data. One of the primary advantages of employing UAVs for topographical mapping is their ability to transcend the constraints of traditional approaches, such as satellite and manned aircraft images. UAVs can access and capture data from areas that were previously difficult or impossible to reach, enabling a more comprehensive and detailed understanding of the landscape. Additionally, the flexibility and maneuverability of these aerial platforms allow for more targeted and efficient data collection, leading to improved mapping accuracy and efficiency.

Figure 2.1: Image of a Drone (Source: https://www.fly-robotics.com/ground-school/)

2.4 DRONE DATA COLLECTION

The use of drones, or Unmanned Aerial Vehicles, has revolutionized the field of geospatial data collection. These aerial platforms, equipped with advanced cameras, sensors, and GPS technology, enable the capture of high-resolution imagery, video, and other valuable data over vast or hard-to-reach areas. The collected information is then processed and analyzed to generate detailed maps, models, and insights, which find applications across industries such as construction, agriculture, surveying, environmental monitoring, and emergency response.

Propeller, a leading player in this domain, has developed an integrated solution combining specialized hardware and software to enhance surveying and mapping operations. They collaborate with top drone manufacturers to ensure their UAVs are fitted with high-precision GNSS receivers and sensors, including portable AeroPoints to ensure accurate data collection and mapping. Propeller's cloud-based platform then processes the raw data, generating detailed 3D models, orthomosaics, and providing user-friendly analytics tools for volume calculations and progress tracking. This end-to-end solution enables efficient and accurate geospatial data collection, streamlining the entire process for its users.

2.4.1 APPROACHES EMPLOYED BY DRONE DATA COLLECTION:

1. **Aerial Photography and Videography**: Captures high-resolution images and videos of landscapes and structures.
2. **Photogrammetry**: Uses overlapping images to create detailed 2D maps and 3D models of terrains and objects.
3. **LiDAR Data**: Collects precise 3D point clouds for accurate mapping of terrain, vegetation, and structures.
4. **Thermal and Multispectral Imaging**: Captures thermal data to assess heat signatures

These approaches offer significant perspectives for diverse applications across industries, enhancing the overall effectiveness of drone data collection.

2.4.2 THE ADVANTAGES OF DATA COLLECTION WITH THE USE OF DRONES

The usage of drones for data collection has the following advantages;

- High Efficiency
- Cost-Effectiveness
- High Precision and Accuracy
- Access to Hard-to-Reach Areas
- Real-Time Data Collection and Processing

2.4.3 ATTAINABLE RESULTS THROUGH DRONE MAPPING:

- **Orthomosaic maps**

An orthomosaic map is a high-resolution, georeferenced image that is made by stitching together several aerial photos that have been adjusted for distortion to give a precise depiction of the surface of the Earth. Drone images are post-processed to remove distortions and create an extremely accurate orthomosaic map by stitching the images together. This map's pixels each include 2-dimensional geographic data (X, Y), making it possible to determine surface areas and horizontal distances with accuracy. Orthomosaic map files are commonly stored in the following file formats: geoTIFF (.tiff), jpg, png, and Google tiles (.kml,.html).

Figure 2.2: Study area orthomosaic map (UGBOWO CAMPUS)

- **3D point cloud**

3D point clouds are created by taking numerous overlapping photos or laser scans of an object or environment and then processing the data to produce a set of points representing the spatial coordinates of the surfaces. Common file formats for this data include .las, .laz, .ply, and .xyz.

- **Digital Surface Models (DSM):**

Digital Surface Models (DSMs) are generated by processing aerial or satellite imagery to provide a 3D depiction of the Earth's surface, including all features such as buildings and vegetation. Common file formats for these models include GeoTIFF (.tif), .xyz, .las, and laz.

- **Digital terrain model (DTM):**

Digital Terrain Models (DTMs) are produced by processing elevation data obtained from various sources, such as LiDAR or photogrammetry, to provide a continuous depiction of the bare ground surface, eliminating vegetation and structures. Once objects like buildings have been filtered out, the drone imagery can be utilized to generate Digital Terrain Models (DTMs), where each pixel represents 2.5D information, including the X, Y coordinates and the Z value corresponding to the highest elevation. The resulting files can be saved in GeoTiff format (.tif).

- **3D textured mesh:**

3D textured meshes are generated by merging a 3D point cloud with texture data from photographs, which is then mapped onto the mesh's surface to produce a realistic, detailed depiction of the object's appearance and features. Supported file formats include .ply, .fbx, .dxf, .obj, and .pdf.

- **Contour lines:**

Contour lines are generated by connecting points of equal elevation on a map, which are often acquired from digital elevation models (DEMs) or other topographical data, to reflect the shape and relief of the landscape. The provided file formats include .shp, .dxf, and .pdf.

CHAPTER THREE

3.1 METHODOLOGY

The following sections present the tools and techniques adopted in achieving the aim and objectives of the project work. This runs from reconnaissance to flight planning, data acquisition to data processing with appropriate software, data analysis, and personnel involved.

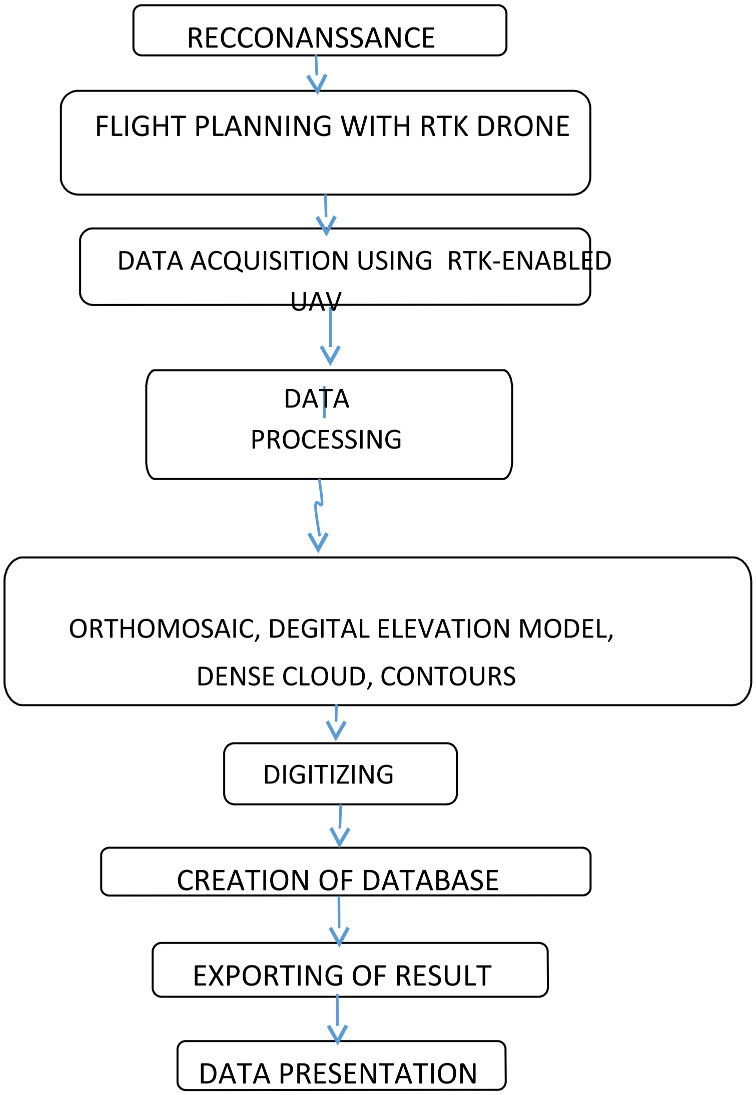


Fig 3.1 WORK FLOW

3.2 STUDY AREA

The University of Benin (UNIBEN) Ugbowo Campus is located in Benin City, Edo State, Nigeria. It is situated along the Benin-Lagos Expressway, making it easily accessible from various parts of the city and beyond.

The study area is located at 6° 24' 15.46"N latitude and 5° 38' 8.11"E longitude.

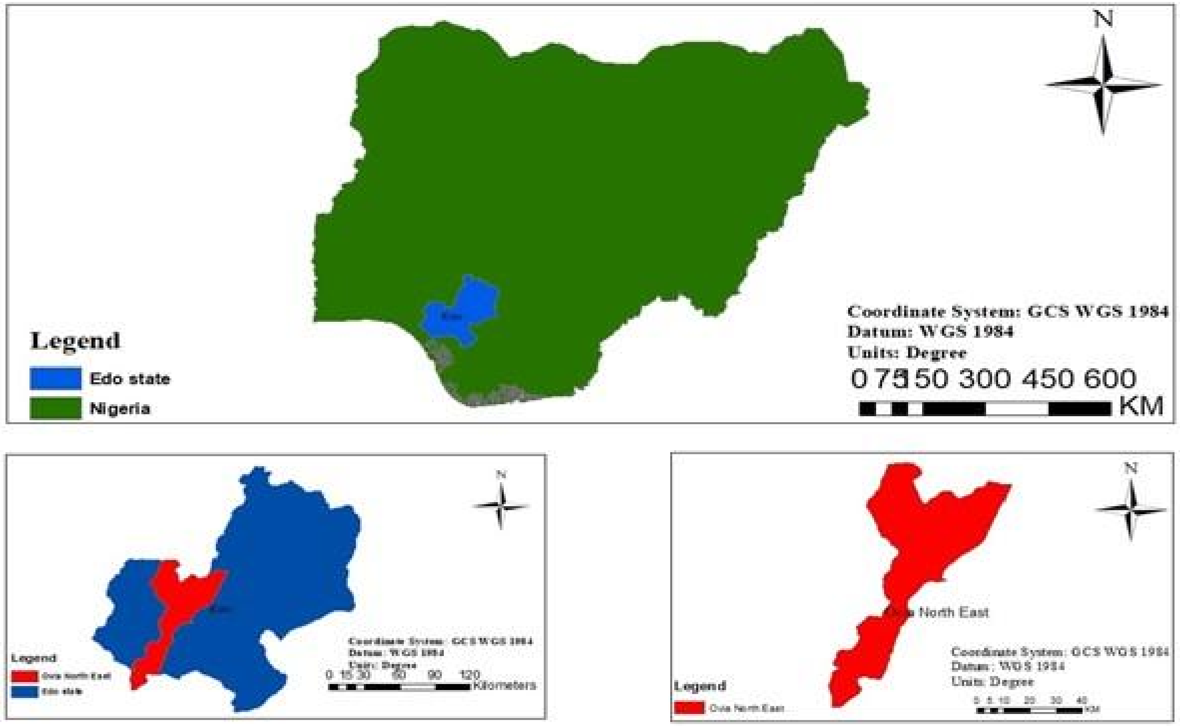


Fig 3.2: Study Area Map

3.3 RECONNAISSANCE SURVEY

A reconnaissance survey is a vital step in the preparatory phase of surveying. It involves an initial evaluation of the campus, during which relevant data—such as topographic maps, aerial photographs, and site plans—are carefully analyzed. This process helps clarify the survey's objectives, ascertain the necessary level of accuracy, select suitable instruments, and establish the most effective methodology to adopt. Furthermore, a work plan is developed to ensure the project is completed efficiently and as swiftly as possible while maximizing the use of available resources.

The reconnaissance survey comprises two distinct methods: office reconnaissance and field reconnaissance.

3.4 OFFICE RECONNAISSANCE

This preliminary stage involves conducting a reconnaissance survey prior to visiting the project site. It is essential to perform background research on the area before starting fieldwork, as this information is vital for the surveyor. In this study, we reviewed various existing resources that provided relevant data about the location. Additionally, a visit was made to the Department of Surveying and Geo informatics at the University of Benin to verify the coordinates of control points near the study area. Other reference materials included Google Earth aerial imagery, previous research projects on similar subjects, textbooks, and various technical documents. This initial investigation was instrumental in estimating project costs, planning the execution timeline, identifying control stations on campus, selecting an appropriate mapping scale, and determining the most effective survey methodology.

3.5 FIELD RECONNAISSANCE

This process involved conducting an on-site inspection of the survey area to gather firsthand information about the terrain, existing control points, accessibility, and potential obstacles before undertaking a detailed survey. We assessed the terrain and identified possible challenges. This preliminary survey allowed us to validate existing data, establish suitable takeoff and landing zones, and optimize flight paths for accurate data collection. By observing ground conditions directly, we were able to anticipate difficulties and make necessary adjustments, ultimately enhancing the efficiency and accuracy of the mapping process.

3.6 SURVEY REFERENCE SYSTEM

The survey was carried out with reference to RALPH GNSS 06 one of the primary controls in the University of Benin Ugbowo campus. The Control is in UTM Zone 31 Coordinate System and WGS 84 Datum.

Station ID	Easting(m)	Northing(m)	Longitude	Latitude	Height(m)
RALPH GNSS 06	790634.4358	708614.1895	6°24’16.726”	5°37’37.919”	110.5127

Table 3.1 Uniben control point

3.7 FLIGHT PLANNING

Flight planning with an RTK drone incorporates real-time kinematic corrections, resulting in high-precision georeferenced data. The method entails establishing a base station or network connection, defining the flight path with precise waypoints, and configuring appropriate altitude and overlap for mapping. Before flight, RTK connectivity is checked to ensure centimeter-level precision. The drone follows the pre-programmed route, taking precise data with minimum ground control points (GCPs) and producing high-accuracy outputs for mapping and surveying.

3.8 GPS- RTK SURVEY

The GPS-RTK survey was executed utilizing an RTK-enabled drone, which functioned as the rover. A base station was established at a known coordinate and consisted of a stationary GNSS receiver. This base station continuously received satellite signals and calculated correction data to mitigate atmospheric interference and satellite drift. The real-time corrections were transmitted to the drone via a radio link, allowing it to achieve centimeter-level accuracy in georeferenced imagery and terrain data. This method reduces the reliance on ground control points (GCPs), significantly enhancing efficiency in topographic mapping and digital terrain modeling.

3.9 DATA COLLECTION WITH UAV

The use of Real-Time Kinematic (RTK) drones in topographic mapping and surveying significantly improved the accuracy and efficiency of data collection. RTK technology enhanced positioning precision by correcting GPS signals in real time, reducing errors to the centimeter level. However, to fully utilize this technology, it was essential to follow proper procedures when deploying, monitoring, and landing the UAV to ensure safety and data reliability.

Deploying the UAV

To ensure a successful and seamless flight, a series of pre-flight checks were performed prior to the deployment of the UAV. Firstly, the survey site was carefully examined for any obstructions that might impede the drone's flight path, such as buildings, trees, and power lines. Moreover, the weather conditions were assessed, as poor visibility, rain, or strong winds could compromise data accuracy and overall flight stability.

Once the site was confirmed to be safe, the next step involved setting up the RTK system. The RTK base station was strategically positioned in an open area with an unobstructed view of the sky to ensure a strong satellite connection. Next, the drone was calibrated, which included adjustments to its inertial measurement unit (IMU), compass, and RTK module for optimal flight stability. The UAV and remote controller were fully charged and securely linked. Finally, the flight plan—detailing the area to be mapped and the designated waypoints—was uploaded to the drone using flight planning software such as DJI GS Pro, Pix4D, or DroneDeploy.

After finalizing all preparations, the UAV was deployed. The process began by powering on the RTK base station to establish a stable connection with the drone. Subsequently, the UAV and remote controller were activated, followed by a thorough check to ensure the RTK status displayed "Fixed," which indicated that the drone was receiving accurate positioning corrections. Once all systems were confirmed to be functioning properly, takeoff was initiated either manually via the remote controller or automatically through the flight planning software.

Monitoring the UAV During Flight

Upon takeoff, the UAV was meticulously monitored to ensure that the mission unfolded as intended. Throughout the flight, the UAV’s position, altitude, battery level, and RTK signal status were carefully tracked. Maintaining a strong RTK connection was crucial for high-precision data collection, and the status remained "Fixed" for most of the flight. In instances where the status shifted to "Float" or "Single," prompt adjustments were made to restore accuracy.

The operator maintained a vigilant oversight for any unexpected obstacles or environmental changes throughout the UAV operation. Although the RTK drone was equipped with sophisticated obstacle avoidance sensors, manual interventions were sometimes necessary to ensure safe navigation. In instances where the drone encountered challenges such as signal interference or physical obstructions, the operator adeptly made adjustments using the remote controller to facilitate a smooth flight. When GPS or RTK signals were temporarily lost, the mission was paused until a stable connection was re-established, thereby preserving the integrity of the data collected.

Battery levels were also monitored closely. The remaining flight time was assessed to ensure the UAV had sufficient power to complete the mission and return safely. If the battery level dropped below the safe threshold, the UAV was immediately recalled to prevent an emergency landing.

Landing the UAV

As the UAV completed its mission, careful landing procedures were followed to ensure a safe descent. Prior to initiating the landing process, the designated landing zone was thoroughly inspected to verify that it was clear of people, vehicles, and obstacles. If the flight planning software featured an automated return-to-home (RTH) function, it was activated, allowing the drone to autonomously navigate back to its takeoff point. Alternatively, the operator could manually guide the UAV to a suitable landing location.

During descent, a controlled and gradual approach was employed to prevent hard landings that could potentially damage the drone. For UAVs operating in rugged or uneven terrain, additional care was taken to identify a stable landing spot. In certain instances, a hand-catch method was utilized for smaller UAVs, but only under stringent safety protocols.

Once the UAV landed safely, the RTK system was efficiently powered down. All collected data was securely stored for thorough post-processing and analysis. The drone's batteries were promptly removed and recharged, ensuring optimal readiness for future flights.

3.10 DATA PROCESSING

Data processing involves presentation of the processed data as result. This process includes downloading of UAV images, processing of the images, downloading of DGPS observation, sorting of data, estimation of vertical difference.

The field results were processed using Agisoft Metashape software. This software has a userfriendly interface with rich functionality and the ability to process large data sets using NVIDIA CUDA cores.

The processing of UAV images involves transforming raw aerial photographs into accurate geospatial products. The process begins by correcting distortions in the images and georeferencing them using GPS data or Ground Control Points. Subsequently, overlapping images are seamlessly stitched together to create an orthomosaic. Utilizing photogrammetric techniques, 3D point clouds are generated, from which elevation models—such as Digital Surface Models (DSM) and Digital Terrain Models (DTM)—are derived to accurately represent surface and terrain features.

The field results were processed using Agisoft Metashape software, known for its intuitive user interface and extensive functionality. This software is adept at handling large data sets and utilizes NVIDIA CUDA cores to significantly enhance processing speed. As a result, it ensures efficient analysis and produces high-quality geospatial products from UAV imagery.

Processing of images with AGISOFT METASHAPE includes the following main Steps:

a. Loading Images into Agisoft Metashape and convert to a coordinate system
b. Verifying RTK Geotag Accuracy
c. Aligning photos
d. Geo-referencing
e. Building Dense Point Cloud
f. Building Mesh (3d Polygonal Model)
g. Generating Texture
h. Building Tiled Model
i. Building Digital Elevation Model (Dem)
j. Building Orthomosaic
k. Exporting Results
l. Generating Report

1. Loading Images and Setting the Coordinate System

The images captured by the RTK drone are imported into Agisoft Metashape. Because these images contain RTK geotags, they are embedded with precise coordinates. The relevant coordinate system, such as WGS84 UTM Zone 32N, is then selected to correspond with the survey requirements.

2. **Checking RTK Geotags for Accuracy**

Instead of importing GCPs, the software uses RTK-corrected coordinates from the image metadata. The RTK fix status is verified to ensure it remained "Fixed" throughout the flight, indicating that corrections were successfully implemented. If any photos have lower accuracy (e.g., "Float" or "Single" status), changes may be required.

3. **Aligning Photos**

The software analyzes the images by detecting common points (tie points) between overlapping photos. RTK geotags offer exact positioning, therefore the alignment is more accurate than traditional GPS-based processing. This phase guarantees that all images are properly aligned with one another and the real-world coordinate system.

4. **Geo-Referencing Using RTK Data**

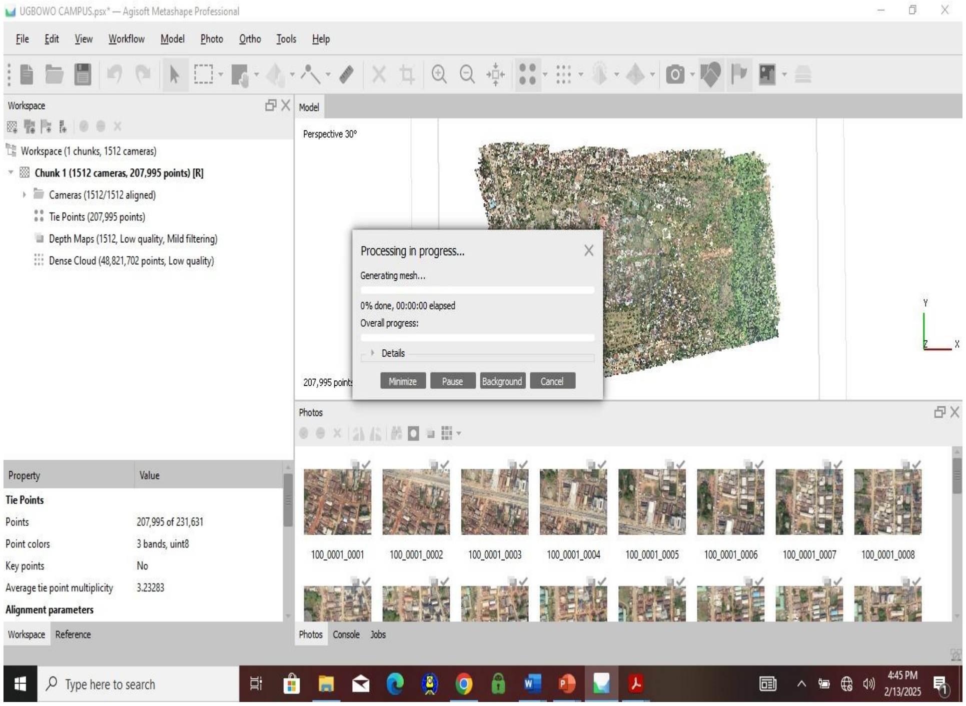
RTK geotags automatically georeference the images during alignment. Unlike traditional workflows that involve manual GCP marking, this stage is completely automated simply due to the drone's onboard RTK technology, which delivers extremely accurate positional data.

5. **Generating the Dense Point Cloud**

The aligned images are utilized to generate a dense point cloud, which represents the surveyed area in 3D. The point cloud is improved by eliminating noise and increasing point density in order to capture finer detail.

6. Building the 3D Mesh and Texture

If a 3D model is required, the dense point cloud is converted into a polygonal mesh. Texturing is used to enhance visualization and make the model appear more realistic.



Workspace (1 chunks, 1512 cameras)
- **Chunk 1 (1512 cameras, 207,995 points) [R]**
  - Cameras (1512/1512 aligned)
  - Tie Points (207,995 points)
  - Depth Maps (1512, Low quality, Mild filtering)
  - Dense Cloud (48,821,702 points, Low quality)

Processing in progress...

Generating mesh...

0% done, 00:00:00 elapsed

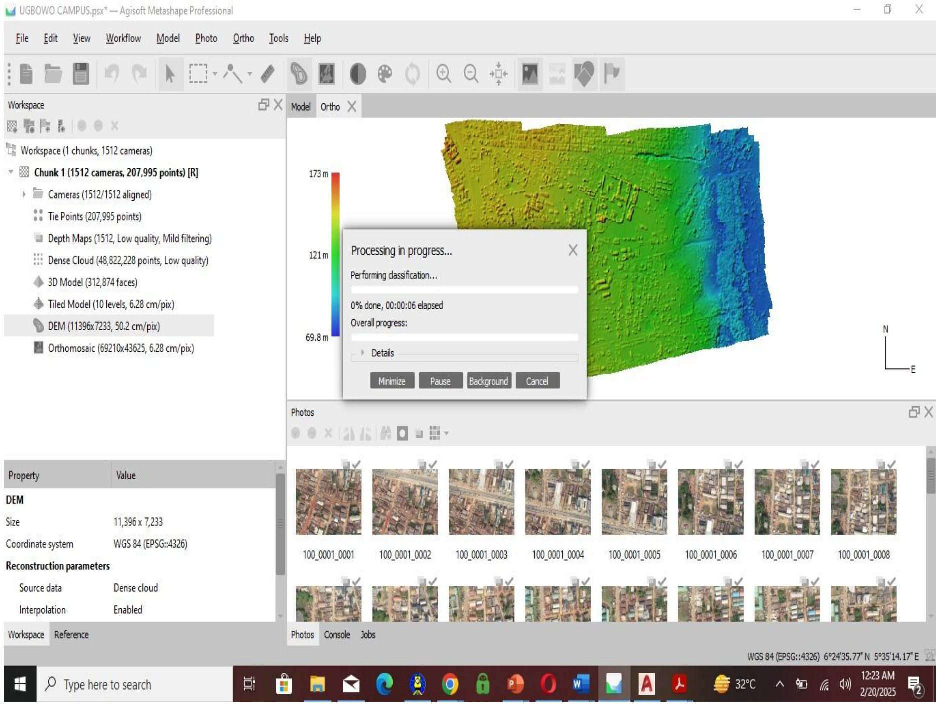
Overall progress:

Property	Value
Tie Points	
Points	207,995 of 231,631
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	3.23283
Alignment parameters	

Fig 3.3 Building mesh dialog

7. Generating the Digital Elevation Model (DEM)

The software processes the point cloud to create a **Digital Surface Model (DSM)** or **Digital Terrain Model (DTM)**. The DSM includes all objects (buildings, vegetation), while the DTM represents the bare ground. These models are essential for terrain analysis.



Workspace (1 chunks, 1512 cameras)
Chunk 1 (1512 cameras, 207,995 points) [R]
  Cameras (1512/1512 aligned)
  Tie Points (207,995 points)
  Depth Maps (1512, Low quality, Mild filtering)
  Dense Cloud (48,822,228 points, Low quality)
  3D Model (312,874 faces)
  Tiled Model (10 levels, 6.28 cm/pix)
  DEM (11396x7233, 50.2 cm/pix)
  Orthomosaic (69210x43625, 6.28 cm/pix)

Property	Value
DEM	
Size	11,396 x 7,233
Coordinate system	WGS 84 (EPSG::4326)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled

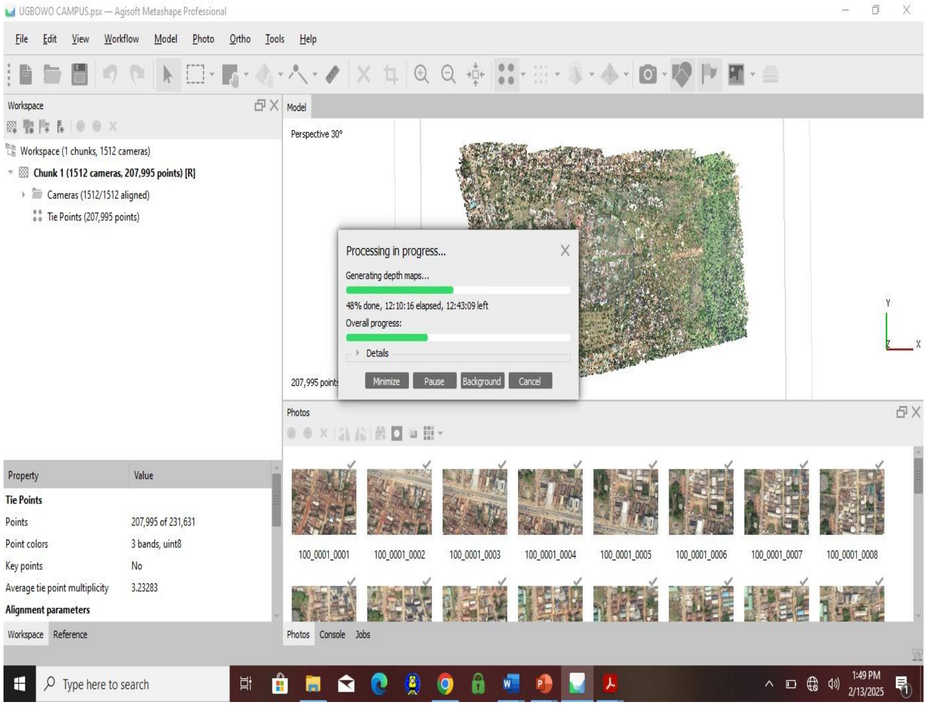
Processing in progress...
Performing classification...
0% done, 00:00:06 elapsed
Overall progress:

WGS 84 (EPSG::4326) 6°24'35.77"N 5°35'14.17"E

Fig 3.4 Generating DEM dialog

8. Creating the Orthomosaic

The aligned and georeferenced images are stitched together to form a high-resolution **orthophoto**. This orthomosaic is corrected for distortions, ensuring accurate scale and positioning.



Workspace (1 chunks, 1512 cameras)
Chunk 1 (1512 cameras, 207,995 points) [R]
Cameras (1512/1512 aligned)
Tie Points (207,995 points)

Processing in progress...
Generating depth maps...
48% done, 12:10:16 elapsed, 12:43:09 left
Overall progress:

207,995 points

Property	Value
Tie Points	
Points	207,995 of 231,631
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	3.23283
Alignment parameters	

100_0001_0001
100_0001_0002
100_0001_0003
100_0001_0004
100_0001_0005
100_0001_0006
100_0001_0007
100_0001_0008

Fig 3.5 Creating orthophoto dialog

9. Exporting Final Results

The processed outputs, including the **orthomosaic, DEM, point cloud, and 3D models**, are exported in suitable formats (GeoTIFF, LAS, OBJ) for further analysis in GIS or CAD software.

10. Generating the Processing Report

A final report is generated, summarizing the processing workflow, accuracy assessment, and quality of the final dataset. This helps verify the precision of the RTK-based survey.

CHAPTER FOUR

RESULT AND ANALYSIS

The following section is devoted for the results obtained in accordance to the set objectives.

4.1 RESULTS

The result of most survey works is an imagery, map or plan. The achieved results after proper execution of the project were presented in figures below

Fig 4.1 Orthomosaic of the study area

4.2 SURVEY DATA

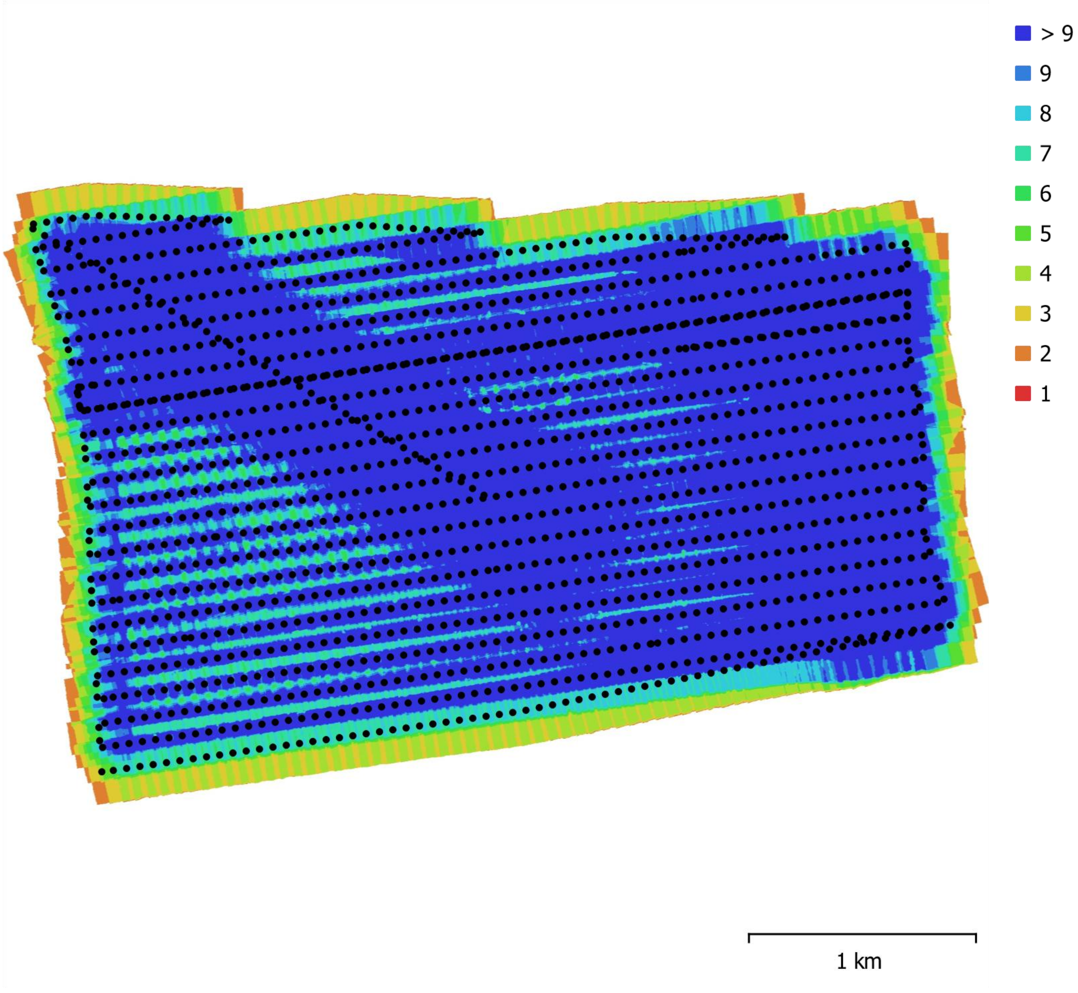


Fig 4.2: Camera locations and image overlap

Number of images:	1,512	Camera stations:	1,512
Flying altitude:	231 m	Tie points:	207,995
Ground resolution:	6.28 cm/pix	Projections:	635,671
Coverage area:	9.59 km²	Reprojection error:	5.41 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC6310R (8.8mm)	4864 x 3648	8.8 mm	2.61 x 2.61 μm	No

Table 4.1: Cameras

4.3 Camera Calibration

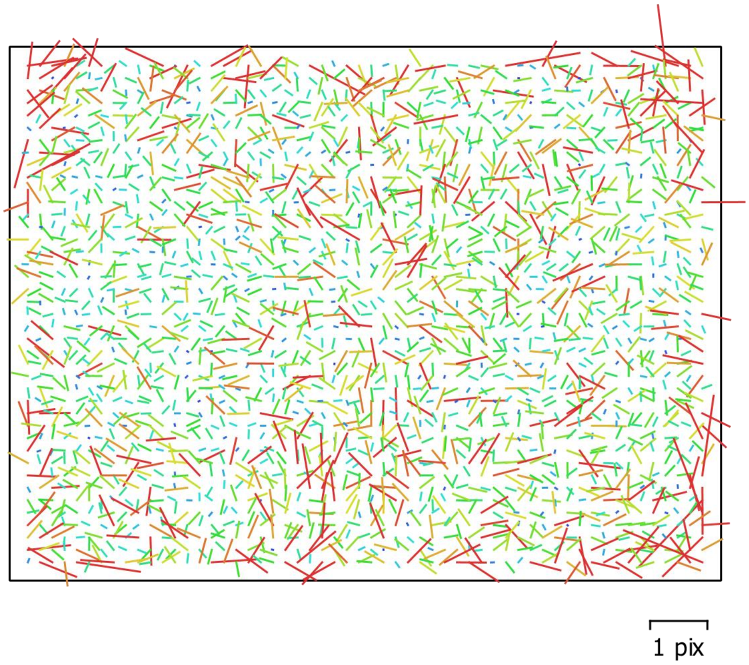


Fig. 4.3: Image residuals for FC6310R (8.8mm).

FC6310R (8.8mm) 1512 images			
Type	Resolution	Focal Length	Pixel Size
Frame	**4864 x 3648**	**8.8 mm**	**2.61 x 2.61 µm**

	Value	**Error**	**K1**	**P1**	**P2**
F	**3372.58**				
K1	**-0.00528724**	4.9e-005	1.00	0.02	0.01
P1	**-0.00112765**	2.1e-005		1.00	-0.03
P2	**0.000342792**	2.1e-005			1.00

Table 4.2. Calibration coefficients and correlation matrix.

4.4 Camera Locations

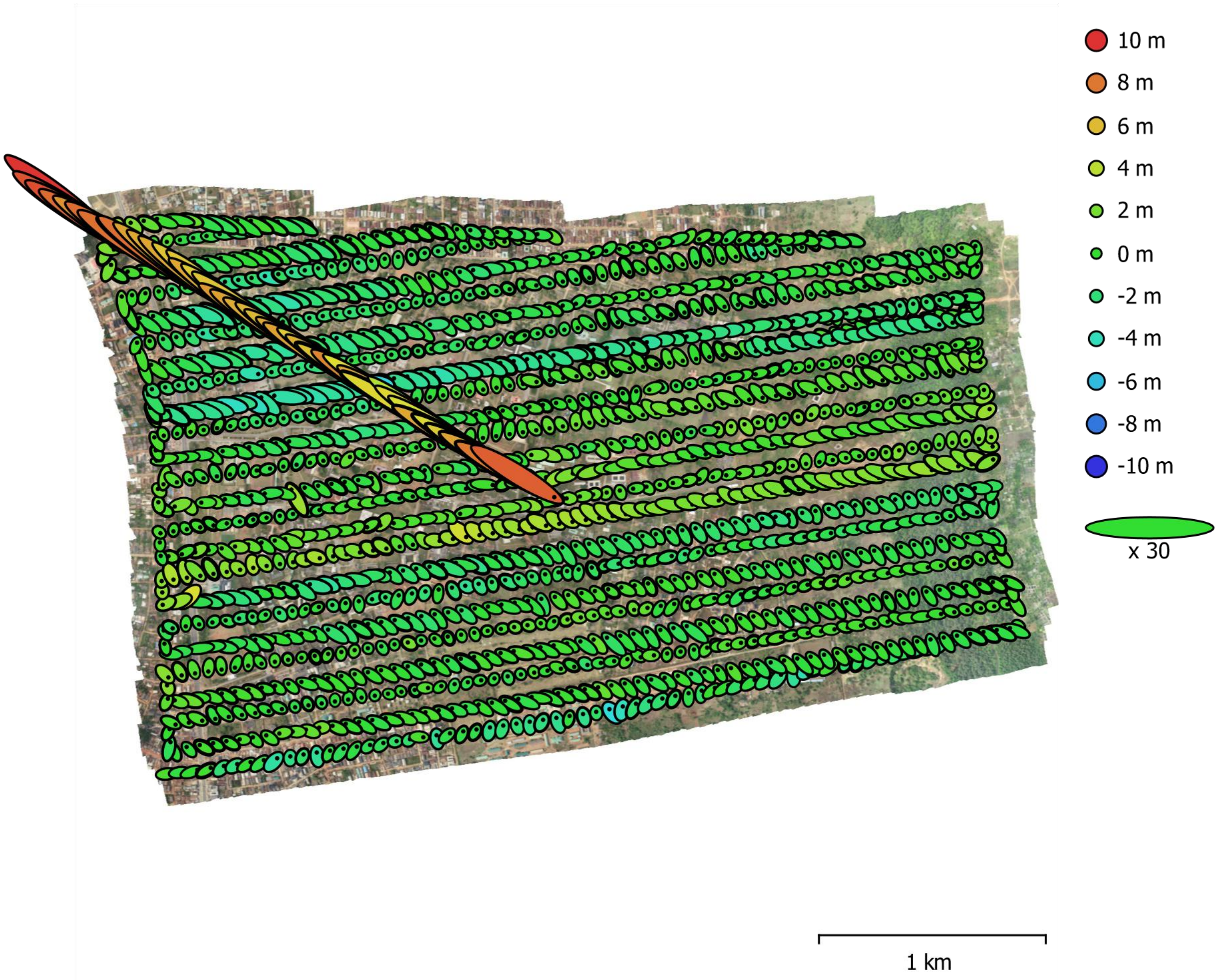


Fig. 3. Camera locations and error estimates.

Fig 4.4: Camera locations and error estimates

Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.

Estimated camera locations are marked with a black dot.

X error (m)	**Y error (m)**	**Z error (m)**	**XY error (m)**	**Total error (m)**
2.52007	1.61573	1.71372	2.99355	3.44937

Table 4.3. Average camera location error. X - Longitude, Y - Latitude, Z -Altitude.

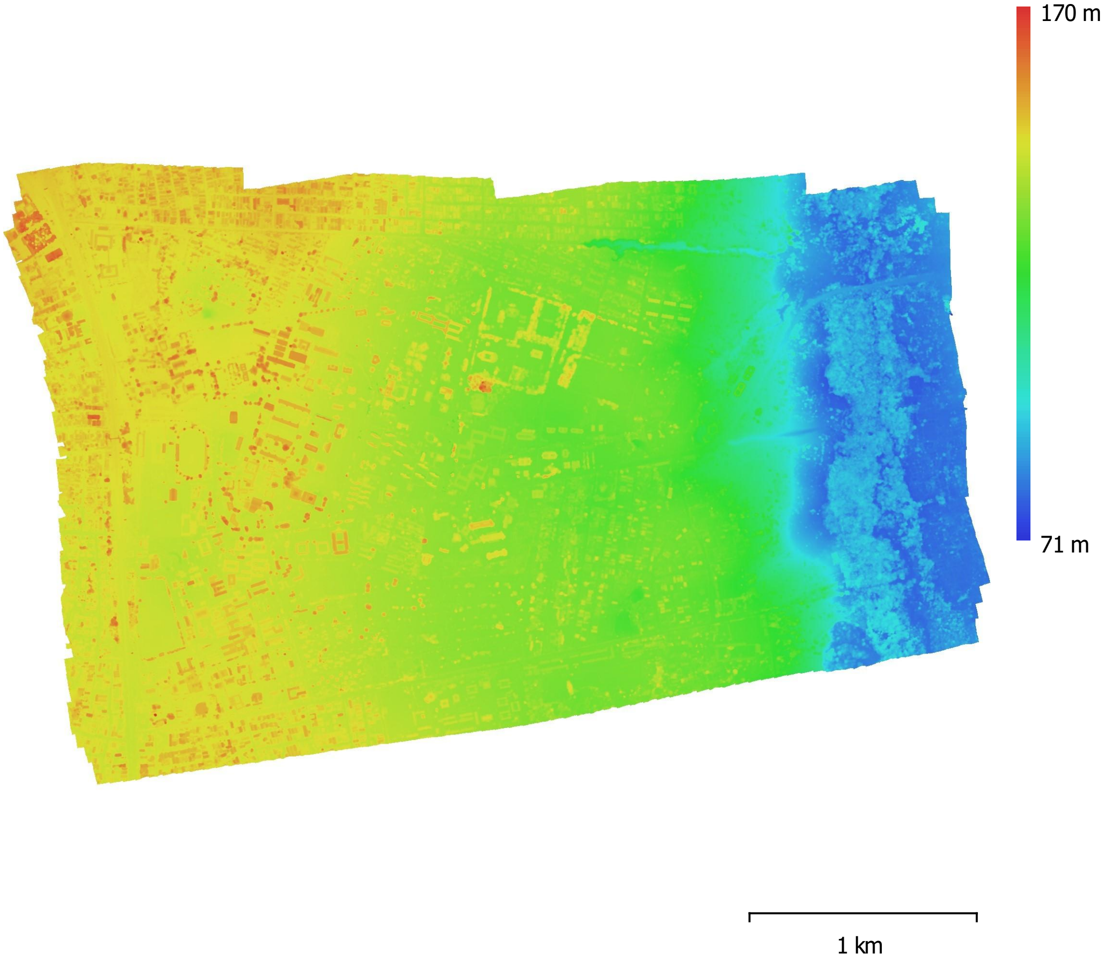


Fig. 4. Reconstructed digital elevation model.

4.5 Digital Elevation Model

Fig 4.5: Reconstructed digital elevation model

Resolution:	50.2 cm/pix
Point density:	3.97 points/m²

4.6 TOPOGRAPHIC MAP OF UGBOWO CAMPUS

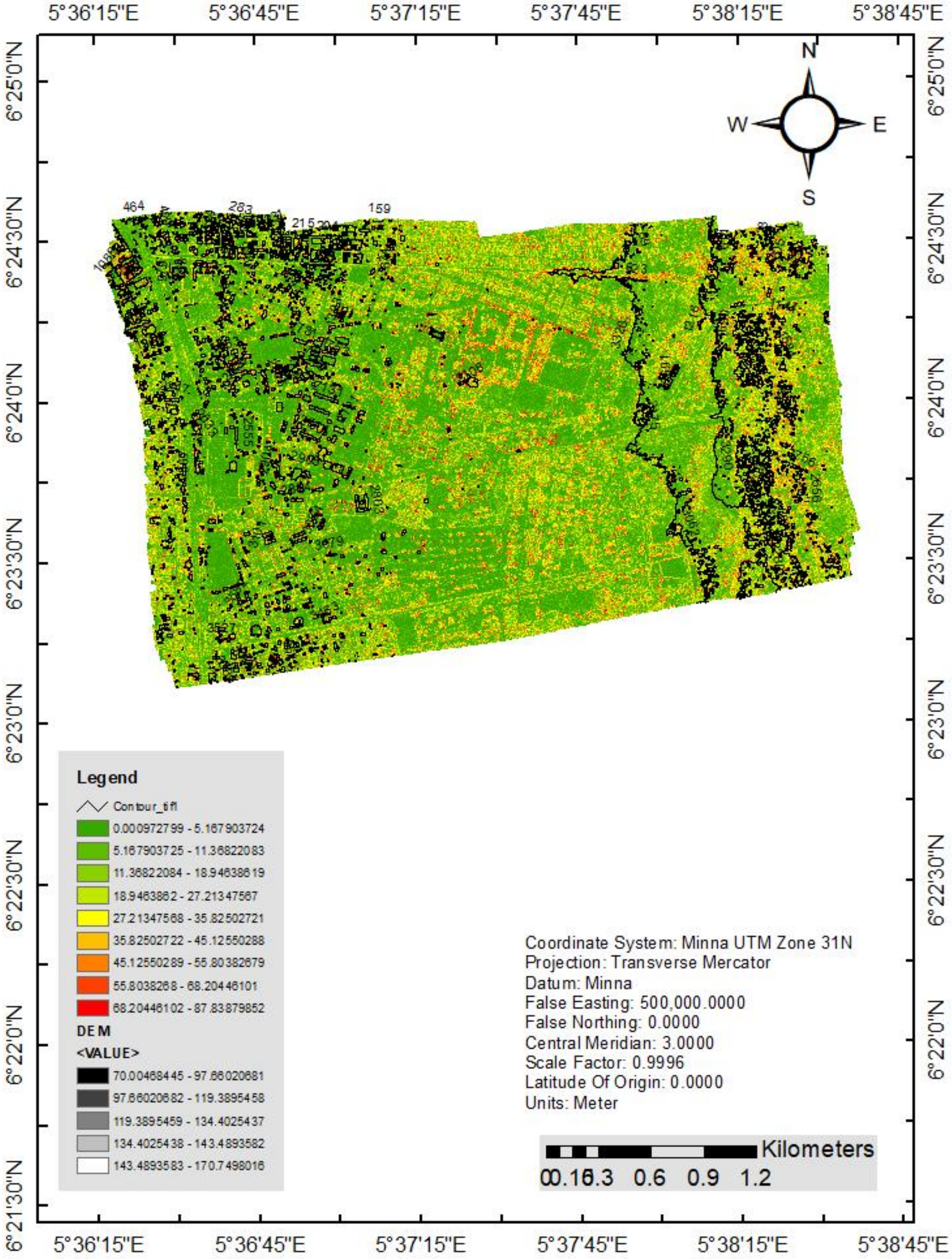


Fig 4.6: Topographic Map of the Study Area

4.7 Processing Parameters

General

Cameras	1512
Aligned cameras	1512
Coordinate system	WGS 84 (EPSG::4326)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	207,995 of 231,631
RMS reprojection error	0.165583 (5.40624 pix)
Max reprojection error	0.502381 (74.5119 pix)
Mean key point size	31.3436 pix
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	3.23283
Alignment parameters	
Accuracy	Lowest
Generic preselection	Yes
Reference preselection	Yes
Key point limit	40,000
Tie point limit	4,000
Adaptive camera model fitting	Yes
Matching time	40 minutes 2 seconds
Alignment time	18 minutes 34 seconds
Software version	1.5.2.7838
Depth Maps	
Count	1512
Depth maps generation parameters	
Quality	Low
Filtering mode	Mild
Processing time	17 hours 0 minutes
Software version	1.5.2.7838
Dense Point Cloud	
Points	48,822,228
Point colors	3 bands, uint8
Depth maps generation parameters	
Quality	Low
Filtering mode	Mild
Processing time	17 hours 0 minutes
Dense cloud generation parameters	
Processing time	1 hours 30 minutes
Software version	1.5.2.7838

Model	
Faces	312,874
Vertices	156,510
Vertex colors	3 bands, uint8
Texture **Depth maps generation parameters**	4,096 x 4,096, 4 bands, uint8
Quality	Lowest
Filtering mode	Mild
Processing time	1 hours 8 minutes

Reconstruction parameters

General

Surface type	Arbitrary
Source data	Depth maps
Interpolation	Enabled
Strict volumetric masks	No
Processing time **Texturing parameters**	1 days 22 hours
Blending mode	Mosaic
Texture size	4,096
Enable hole filling	Yes
Enable ghosting filter	Yes
UV mapping time	8 seconds
Blending time	14 hours 9 minutes
Software version **Tiled Model**	1.5.2.7838
Texture	3 bands, uint8

Depth maps generation parameters

Quality	Low
Filtering mode	Mild
Processing time **Reconstruction parameters**	17 hours 0 minutes
Source data	Dense cloud
Tile size	256
Face count	Low
Processing time	1 days 15 hours
Software version **DEM**	1.5.2.7838
Size	11,396 x 7,233
Coordinate system **Reconstruction parameters**	WGS 84 (EPSG::4326)
Source data	Dense cloud
Interpolation	Enabled
Processing time	4 minutes 45 seconds
Software version **Orthomosaic**	1.5.2.7838
Size	69,210 x 43,625
Coordinate system	WGS 84 (EPSG::4326)
Colors **Reconstruction parameters**	3 bands, uint8
Blending mode	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	5 hours 21 minutes
Software version **Software**	1.5.2.7838
Version	1.5.2 build 7838
Platform	Windows 64

4.8 ANALYSIS

The process of generating a topographic map of the Ugbowo campus using the DJI Phantom 4 RTK involves a structured workflow that integrates precise UAV photogrammetry with real-time kinematic positioning. By leveraging the RTK system, the UAV captures georeferenced images with centimeter-level accuracy, reducing the dependence on ground control points while ensuring high spatial precision. Careful flight planning determines optimal altitude, image overlap, and flight speed to maximize coverage and resolution. The UAV follows a predefined path, systematically capturing overlapping images that will later be processed into detailed geospatial outputs.

Once the data is acquired, the images are imported into photogrammetry software for processing. The first step involves aligning the images using tie points to generate a sparse point cloud, followed by the creation of a dense point cloud that represents the terrain in high detail. From this data, a Digital Elevation Model (DEM) is extracted, accurately depicting variations in elevation across the campus. The DEM serves as a foundation for terrain analysis, allowing for contour generation and hydrological modeling.

Simultaneously, the software processes the georeferenced images to generate an orthophoto—a high-resolution, geometrically corrected aerial image that provides an accurate representation of the campus without distortions. This orthophoto can be used for detailed mapping, infrastructure planning, and land-use analysis. By integrating both the DEM and orthophoto, a comprehensive topographic dataset is produced, offering a precise visualization of the landscape and its features.

This UAV-based mapping approach significantly enhances surveying efficiency by reducing field time while maintaining high accuracy. The final outputs—DEM, orthophoto, and contour maps—serve as valuable resources for geospatial analysis, aiding decision-making in infrastructure development, environmental planning, and academic research within the University of Benin.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The deployment of Unmanned Aerial Vehicles (UAVs) for topographic mapping has proven to be exceptionally efficient in geospatial data collection. This study illustrates the capabilities of UAV technology in capturing high-resolution imagery and producing accurate topographic representations of the University of Benin’s main campus. A key advantage of utilizing UAVs is their ability to access challenging or hazardous terrains, thereby mitigating the risks associated with traditional ground-based surveys while enhancing operational efficiency. When compared to conventional surveying techniques, UAV-based mapping offers a quicker, more cost-effective, and adaptable method for data acquisition, enabling frequent updates and improved spatial analysis.

A critical aspect of this research was the verification of data accuracy prior to the production of the final topographic map. Ensuring the reliability of the information derived from UAV imagery was essential for maintaining high precision standards. Topographic data plays a vital role in land-use planning, site development, and various geospatial applications. Accurately representing terrain characteristics is crucial for facilitating informed decision-making and optimizing resource management within the mapped area.

Data processing was performed using Agisoft Metashape, which enabled the generation of both a Digital Surface Model (DSM) and a Digital Terrain Model (DTM), providing detailed insights into elevation variations within the study area. Additionally, orthomosaic imagery was analyzed and digitized using ArcGIS 10.7, facilitating the extraction of essential topographic features. These outputs constitute critical datasets for a range of applications that require precise terrain representation.

In summary, this study highlights the efficacy of UAV technology in modern geospatial data collection and mapping. The findings demonstrate the benefits of UAV-based surveys in generating high-resolution topographic models with improved efficiency and accuracy. As technology evolves and enhances UAV capabilities, their role in surveying and mapping is expected to expand, thereby reinforcing their importance within the geomatics field.

5.2 Recommendations

Based on the study's conclusions, recommendations are proposed to enhance the effectiveness of UAV technology in topographic mapping, emphasizing strategies such as:

i. Increasing public awareness of the benefits of digital topographic maps for easier updates and analysis.
ii. Encouraging the use of UAVs in surveying for faster data collection and higher accuracy.
iii. Utilizing advanced photogrammetric software to enhance data processing and terrain modeling.
iv. Performing periodic UAV surveys to ensure topographic data remains up to date.
v. Organizing workshops and training programs for surveyors, students, and professionals to enhance their proficiency in UAV operations and data processing.
vi. Integrating UAV-based surveying into Geomatics and Engineering programs to enhance Universities and technical institutions curriculum with modern technologies

REFERENCES

Colomina, I., & Molina, P. (2014). Unmanned Aerial Vehicles for Photogrammetry and Remote Sensing: A Review. *ISPRS Journal of Photogrammetry and Remote Sensing, 92*, 79-97.

Evans, R.T., and Frye, H.M., 2009, History of the topographic branch (division): U.S. Geological Survey Circular 1341, 196 p.

Goodchild, M. F. (2007). *Citizens as sensors: the world of volunteered geography*. GeoJournal, 69(4), 211-221

James, M. (2015). Urban aerial mapping using UAVs: A case study in Utah. *ISPRS Journal of Photogrammetry and Remote Sensing*, 102, 168-180. https://doi.org/10.1016/j.isprsjprs.2014.05.007

Khelifa, (2017). Use of UAVs for topographical mapping in a coastal area in Algeria. *Journal of Coastal Research*, *33*(6), 1367-1375. https://doi.org/10.2112/JCOASTRES-D-17-00075.1

Kimerling, A. J., & B. C. (2009). *Map use and analysis*. Esri Press.

Lin, (2018). Comparison of UAV-based topographical mapping and traditional ground surveying methods. *Journal of Applied Remote Sensing*, *12*(1), 1-12.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic Information Systems and Science*. John Wiley & Sons.

Mavrou (2024). **The importance of topographical maps in architectural site analysis**. *Mapserve*. Retrieved from https://www.mapserve.co.uk/blog/the-importance-of-topographical-maps-in-an-architectural-site-analysis

McCoy, A. (2014). *Topographic mapping: Techniques and applications*. Springer.

Rajabifard, A., Feeney, M. E. F., & Williamson, I. P. (2006). *Developing Spatial Data Infrastructures: From Concept to Reality*. CRC Press.

Robinson, A. C., & Lindgren, J. J. (2009). *Elements of cartography*. John Wiley & Sons.

Slocum, T. A., McMaster, R. B., & Kessler, F. C. (2009). *Thematic cartography and geographic visualization*. Prentice Hall.

W. J. K. (2005). *Principles of geographical information systems*. Oxford University Press.

Williamson, I., Enemark, S., Wallace, J., & Rajabifard, A. (2010). *Land Administration for Sustainable Development*. Esri Press.