



Palestine Polytechnic University

College of Engineering

Civil Engineering Department

Graduation Project

Using aerial photography techniques to
monitor buildings and enforce building codes

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Hebron - Palestine

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The undersigned hereby certify that they have read, examined, and recommended to the Department of Civil Engineering in the College of Engineering at Palestine Polytechnic University the approval of a project entitled **Using aerial photography techniques to monitor buildings and enforce building codes** by: Aseel Abo Dawod and Baraa Al-Sharif for partial fulfillment of the requirements for the bachelor's degree.

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ABSTRACT

Using aerial photography techniques to monitor buildings and enforce building codes

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Our project aims to use the drone, where several aspects will be studied, starting with the first phase of studying and analyzing the topography of the project site, which is located in the suburb of Al-Hussein / Hebron, on an area of 150 dunums, to produce a topographic map to detect any new changes.

And then raising the buildings in a three-dimensional way so that the number of floors in each building appears in a manner that matches reality, after which the colors of the floors are distinguished according to the existence of the license.

المخلص

استخدام تقنيات التصوير الجوي في مراقبة الأبنية وإنفاذ قوانين البناء

فريق العمل

براء الشريف

أسيل أبو داود

إشراف

م . مصعب شاهين

يهدف مشروعنا إلى استخدام الطائرة بدون طيار، حيث سيتم دراسة عدة جوانب، بدءاً بالمرحلة الأولى الخاصة بدراسة وتحليل تضاريس موقع المشروع الذي يقع في ضاحية الحسين / الخليل، على مساحة 150 دونم، لإنتاج خارطة طبوغرافية لكشف أي تغيرات جديدة.

ومن ثم رفع المباني بشكل ثلاثي الأبعاد بحيث يظهر عدد الطوابق في كل مبنى بشكل مطابق للواقع، بعدها يتم تمييز ألوان الطوابق حسب وجود الرخصة.

DEDICATION

To those who have always believed in us ...

To those who have been our source of inspiration ...

To those who gave us strength ...

To those who provide us their endless support and encouragement ...

To our families ...

to our friends...

To everyone who carries love in his heart for us ...

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CHAPTER 1

INTRODUCTION

1.1 General Overview

Surveying technology has helped us measure for thousands of years, but land surveying technology continues to evolve, and like every industry, the future of land surveying is set to change in the coming years, between the increase in the use of drones and improvements in 3D mapping.

With the boom of technology in these years, we need to keep pace with the technological progress, as our project idea is based on the use of aerial photography in the survey work and building monitoring.

These real-time technologies can be very important to surveyors because they provide better coverage, effort and time when compared to traditional ground surveys, as well as a clearer and more accurate appearance.

1.2 Project Problem

Using traditional survey methods to monitor buildings doesn't cover large areas, can't be detected quickly, or crosses difficult terrain, as surveyors can now obtain data quickly and accurately using modern drones. In addition, drones make measuring safer, since operators no longer need to fly or enter dangerous environments.

1.3 Objectives of the project

This project was selected to achieve the following:

- Developing the techniques used in monitoring buildings and monitoring violations before and after construction.
- Linking the theoretical information acquired during the study period with practical life.
- Surveying a piece of land using a drone.
- Using the aerial image from the drone and inserting it into the agisoft program to create a 3D model.

1.4 Methodology

The municipality provided Information such as the structural plans, and based on discussions with the Department of Buildings and GIS in the Municipality of Hebron, we agreed on this method of work:

Phase 1: Data collection

Determine the work area and then make an exploratory visit to the site and take a complete idea of the nature of the project, the problems related to it, and the important details in order to get the best and most accurate results.

Phase 2: Area of study

Choosing the study area and taking approval from the supervisor, and we set a suitable date for an exploratory tour of the place.

This project area in Hebron is called "Al-Hussein Neighborhood" and covers 150 donum.

Phase 3: Survey works

- A. Choosing and distributing control points.
- B. A drone has flown inside the study area and a picture from the plane was taken.
- C. Photogrammetry modeling: Image processing and linking control points within agisoft program, Include making a 3D model for them to produce orthophoto.

Phase 4: Topographic map

Digitising inside agisoft program, took general points, drew break lines, exported them, and made a Topo Map inside the civil program.

Phase 5: Building monitoring system in Hebron Municipality

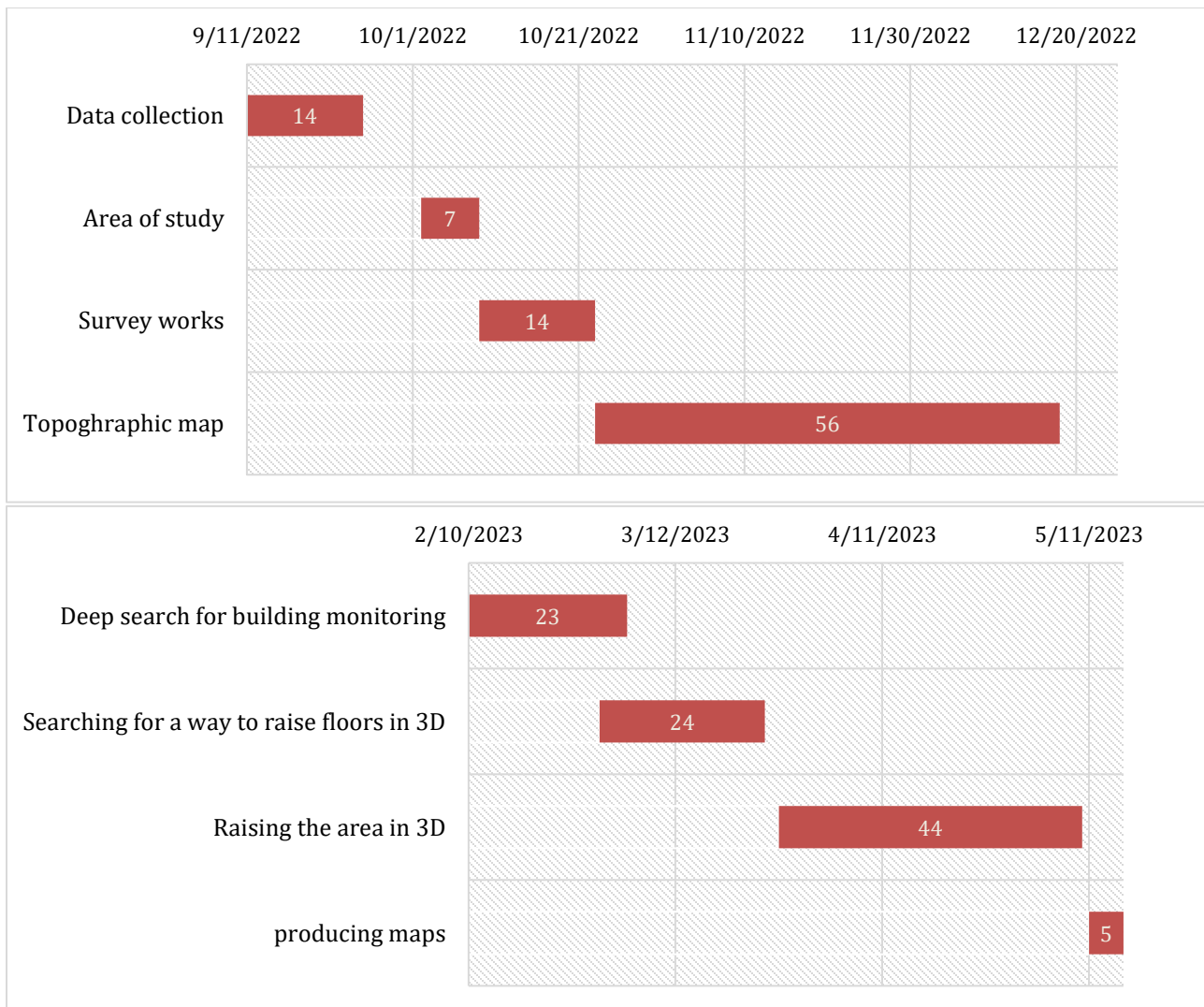
- 1. Number of controlled ponds.
- 2. Hebron Municipality Borders.
- 3. Clarify the work of observers at the moment.
- 4. Proposed mechanism of action by aerial photography.
- 5. Advantages and disadvantages of the current system and the proposed system.

Phase 6: Results and Recommendations

- Surveying science tends to use the most advanced devices in monitoring buildings and survey works, such as drones, as they are safer and faster than traditional devices.
- Keep up with technology and using modern programs related to aerial photography.

1.5 Project timeline

Table (1) Project timeline



1.6 Programs used in the project

- Microsoft Office: It was used in various parts of the project such as text writing, formatting, and project output.

- ArcGIS Pro 3.2
- Agisoft
- Civil 3D
- Simple

1.7 Project challenges

A mechanism for representing the current reality with a virtual reality through which information is analyzed and hypotheses are built through which we can understand the existing reality, find solutions and apply the law.

CHAPTER 2
SURVEYING

2.1 Definition, Categories, and Purpose of Surveying

Surveying is the process of determining the relative position of natural and manmade features on or under the earth's surface, the presentation of this information either graphically in the form of plans or numerically in the form of tables, and the setting out of measurements on the earth's surface. It usually involves measurement, calculations, the production of plans, and the determination of specific locations. The surveyor may be called on to determine heights and distances; to set out buildings, bridges and roadways; to determine areas and volumes and to draw plans at a predetermined scale.

There are two major categories of surveying:

1. **Plane Surveying** Plane surveying deals with areas of limited extent and it is assumed that the earth's surface is a plane and therefore no corrections necessary for the earth's curvature.
2. **Geodetic Surveying** Geodetic surveying is concerned with determining the size and shape of the earth and it also provides a high-accuracy framework for the control of lower order surveys. The highest standards of accuracy are necessary. Geodetic surveys cover relatively large areas (e.g. a state or country) for which the effects of earth curvature must be considered.

Apart from the two main categories, we may also classify surveys according to their different branches and those disciplines directly associated with surveying:

1. **Topographic Surveys** are concerned with the measurement and mapping of the physical features of the earth. These features are all natural and manmade features.
2. **Engineering Surveys** cover surveys carried out as part of the preparation for, and carrying out of, engineering works, including roads, railways, pipelines, drainage etc.
3. **Cadastral Surveys** are concerned with the measurement, definition and mapping and recording of property boundaries.
4. **Hydrographic Surveys** are those made for determining the shape of the bottom of lakes, rivers, harbours and oceans. They also include the measurement of the flow of water in streams and the estimation of water resources.
5. **Aerial Surveys** are made from an aeroplane, and for the purpose of mapping the terrain. The control for such a map is obtained from ground surveys, but the details are obtained from aerial photographs. This includes making measurements and interpretations from aerial photographs.

6. Astronomic Surveys are surveys made to determine the latitude, longitude and azimuth from observations to the stars.

7. Mining Surveys are those made to determine survey control for the development of both surface and underground mines within the mining industry, and the determination of volumes in mine production.

8. Computing is a specialised area of surveying where complex computer programs are used to solve problems within the surveying industry.

9. Consulting is another specialised area of surveying where specialist surveyors are hired for a short period of time to advise on the requirements for a specific task or to perform the specific task. The above surveys have a common stem in skills and training. They have little or nothing in common with marine surveys, public opinion surveys, quantity surveys etc.

2.2 The Survey Process

The following sequence of steps is commonly followed when carrying out a survey:

(i) Reconnaissance During the reconnaissance phase, the surveyor will obtain an overall picture of the area that the project will be conducted in. They will select where the control points will be located, the accuracy required for the control, and which survey instruments will be required for the project.

(ii) Measurement and Marking During the measurement and marking phase, the surveyor will perform all the observations in the field required to accurately determine the control points, as well as placing and observing to any temporary points such as wooden pegs. They would also perform any calculations from the observations, such as angular and linear misclose and area and volume calculations.

(iii) Plan Preparation During the plan preparation phase, the calculations that were performed from the field observations would be further enhanced and used to produce the final plans for the project.

Note:

Control – The accepted surveying practice is to work from the whole to the part when establishing control. That is, select a small number of primary control points that cover the whole area and form a well-defined network of figures. These are broken down into a smaller network of figures as required.

Accuracy – Some projects do not require the highest possible accuracy, and, therefore, it is not always necessary to use the highest possible precision. This point is further reinforced by the usual contracting requirement that the job be done in the shortest possible time at the least possible cost. Equipment and techniques to be used need to be carefully considered so that the project is completed according to instructions, using the most appropriate methods.

2.3 Units of Measurement

SI units the most commonly used in surveying being shown below:

Table (2) Units of Measurement

<u>Quantity</u>	<u>Unit</u>	<u>Symbol</u>
Length	kilometre	km
	metre	m
	millimetre	mm
Area	square metre	m ²
	hectare	ha
Volume	cubic metre	m ³
Angle	degrees	°
	minutes	'
	seconds	"
Mass (Weight)	Kilogram	kg
Temperature	Degrees Celsius	°C

The SI unit for an angle is the radian (rad), but most surveying instruments measure in degrees, minutes and seconds, which is known as the sexagesimal system. This is the only unit of measure that is not SI.

2.4 Six of the Most Common Surveying Instruments

Surveying is one of the oldest professions, with records of land surveys dating back to ancient Roman times. You might assume that equipment used in the past was rudimentary and crude, but evidence indicates that ancient measuring tools for surveying were developed with surprising accuracy. Romans used an instrument called a groma to “trace on the ground simple and orthogonal alignments necessary to the construction of roads, city, temples, and agricultural lands subdivision¹.” Since then, surveying instruments have evolved with respect to exponential developments in technology. These days, surveyors use elite electronic equipment in addition to more basic tools to aid in measuring and mapping efforts. Curious to know more about the equipment surveyors use? We have compiled a list of the six most used surveying tools, including:

1. Theodolite: A surveying instrument with a rotating telescope for measuring horizontal and vertical angles to make precise measurements of areas and triangulate the position of objects in a specific area.



Figure 1-2.4 Theodolite

2. Measuring tape: A length of tape or thin flexible metal, marked at intervals for measuring size or distance. Surveyors commonly use tape measures (known as measuring wheels) in lengths of over 100 meters³.



Figure 2-2.4 Measuring tape

3. Total station: A theodolite that uses electronics to calculate angles and distances and contains an on-board computer to collect data and perform triangulation calculations. This tool is used to record features in topographic surveying or to set out features (roads, houses, or boundaries).



Figure 3-2.4 Total station

4. 3D scanners: A surveying instrument that can accurately measure and collect data from objects, surfaces, buildings, and landscapes. This tool collects information in the form of point cloud data, which consists of millions of 3D coordinates. These coordinates can be used to create 3D computer-aided design (CAD) models, which can then help analyze topographic features and structures. The high accuracy of 3D scanners helps reduce project costs.



Figure 4-2.4 3D scanner

5. Level and rod: A graduated wooden or aluminum rod, used with a levelling instrument to determine the difference in height between points or heights of points above a vertical datum. This tool is used to establish and verify elevations.



Figure 5-2.4 Level and rod

6. GPS/GNSS: The use of Global Positioning System signals and/or Global Navigation Satellite System signals via a receiver and antenna to determine the form, boundary, position, objects, or points in space relative to other forms, boundaries, or points. This technology has dramatically increased the speed and productivity of surveyors using on-demand centimeter-level accuracy provided by Real-Time Kinematic (RTK) positioning.



Figure 6-2.4 GPS/GNSS

GNSS stands for Global Navigation Satellite System, and is an umbrella term that encompasses all global satellite positioning systems. This includes constellations of satellites orbiting over the earth's surface and continuously transmitting signals that enable users to determine their position.

GNSS is used in collaboration with GPS systems to provide precise location positioning anywhere on earth. GNSS and GPS work together, but the main difference between GPS and GNSS is that GNSS-compatible equipment can use navigational satellites from other networks beyond the GPS system, and more satellites means increased receiver accuracy and reliability. All GNSS receivers are compatible with GPS, but GPS receivers are not necessarily compatible with GNSS.

Both GPS and GNSS consist of three major segments: the space segment (satellites), the ground segment (ground control stations), and the user segment (GNSS or GPS receivers), and the exact location of each satellite is known at any given moment. Satellites are continuously sending radio signals toward earth, which are picked up by GNSS or GPS receivers. The ground control stations that monitor the Global Navigation Satellite System continuously track satellites, update the positions of each and enable information on earth to be transmitted to the satellites.

Currently, GNSS/GPS is being used in a variety of fields where the use of precise, continually available position and time information is required, including agriculture, transportation, machine control, marine navigation, vehicle navigation, mobile communication and athletics.

GPS Accuracy:

it depends. GPS satellites broadcast their signals in space with a certain accuracy, but what you receive depends on additional factors, including satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality.

For example, GPS-enabled smartphones are typically accurate to within a 4.9 m (16 ft.)

However, their accuracy worsens near buildings, bridges, and trees.

High-end users boost GPS accuracy with dual-frequency receivers and/or augmentation systems. These can enable real-time positioning within a few centimeters, and long-term measurements at the millimeter level.

Table (3) Control and Check points

Point NO.	Description	Northing	Easting	Elevation	Hz Prec	Vt Prec
2	control point	104094.63	157283.30	965.334	0.012	0.025
4	control point	104077.80	157445.18	967.825	0.010	0.020
5	check point	104018.24	157450.38	963.361	0.012	0.027
7	control point	103959.96	157161.81	954.385	0.014	0.030
8	control point	103960.10	157262.20	957.365	0.011	0.022
9	control point	103765.03	157330.08	951.449	0.012	0.024
10	control point	103725.97	157244.74	942.127	0.013	0.025
11	control point	103967.36	157466.42	959.677	0.028	0.053
14	check point	103834.66	157228.90	946.169	0.012	0.024
16	check point	104019.58	157268.17	961.552	0.010	0.017
17	control point	104135.81	157196.19	955.756	0.012	0.024

2.5 Drone survey

A drone survey refers to the use of a drone, or unmanned aerial vehicle (UAV), to capture aerial data with downward-facing sensors, such as RGB or multispectral cameras, and LIDAR payloads. During a drone survey with an RGB camera, the ground is photographed several times from different angles, and each image is tagged with coordinates.

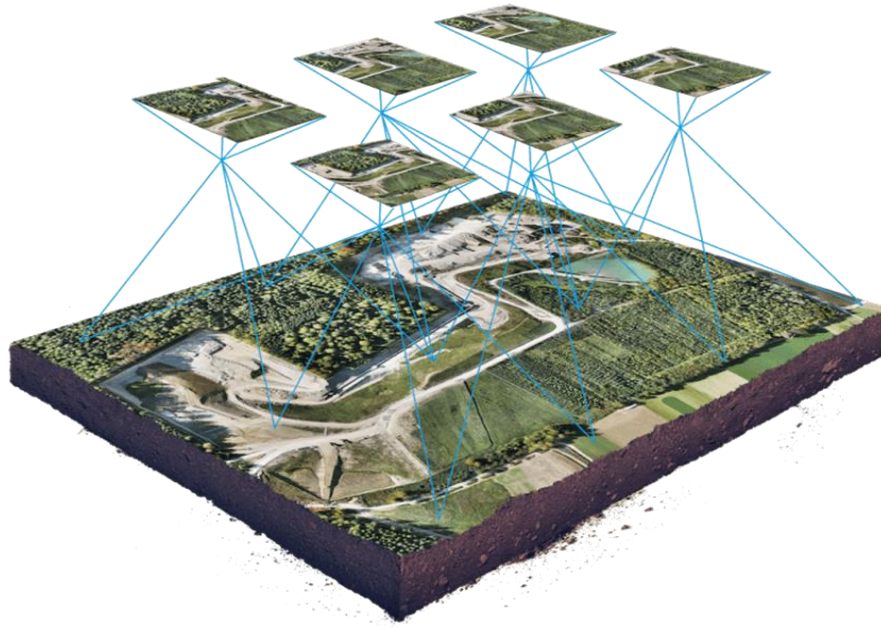


Figure 1-2.5 Photogrammetry images

From this data, a photogrammetry software can create geo-referenced orthomosaics, elevation models or 3D models of the project area. These maps can also be used to extract information such as highly-accurate distances or volumetric measurements.

Unlike manned aircraft or satellite imagery, drones can fly at a much lower altitude, making the generation of high-resolution, high-accuracy data, much faster, less expensive and independent of atmospheric conditions such as cloud cover.

2.6 The benefits of drones in surveying

Some of the benefits of using drones in surveying:

1-Reduce field time and survey costs

Capturing topographic data with a drone is up to five times faster than with land-based methods and requires less manpower. With PPK geo-tagging, you also save time, as placing numerous GCPs is no longer necessary. You ultimately deliver your survey results faster and at a lower cost.

2-Provide accurate and exhaustive data

Total stations only measure individual points. One drone flight produces thousands of measurements, which can be represented in different formats (orthomosaic, point cloud, DTM, DSM, contour lines, etc.). Each pixel of the produced map or point of the 3D model contains 3D geo-data.

3-Map otherwise inaccessible areas

An aerial mapping drone can take off and fly almost anywhere. You are no longer limited by unreachable areas, unsafe steep slopes or harsh terrain unsuitable for traditional measuring tools. You do not need to close down highways or train tracks. In fact, you can capture data during operation without an organizational overhead.

2.7 Uses of drones

1-Land surveying / cartography

Survey drones generate high-resolution orthomosaics and detailed 3D models of areas where low-quality, outdated or even no data, are available. They thus enable high-accuracy cadastral maps to be produced quickly and easily, even in complex or difficult to access environments. Surveyors can also extract features from the images, such as signs, curbs, road markers, fire hydrants and drains.

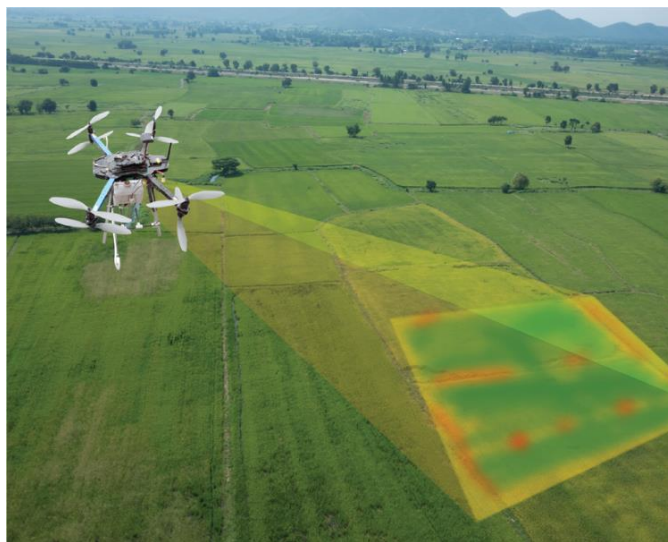


Figure 1-2.7 cadastral map overlaid on aerial images

After post-processing with a photogrammetry software, these same images can produce very detailed elevation models, contour lines and breaklines, as well as 3D reconstructions of land sites or buildings.

2-Land management and development

Aerial images taken by drones greatly accelerate and simplify topographic surveys for land management and planning. This holds true for site scouting, allotment planning and design, as well as final construction of roads, buildings and utilities.



Figure 2-2.7 Using Drones in Construction site monitoring and manegment

These images also provide the foundation for detailed models of site topography for pre-construction engineering studies. The generated data can also be transferred to any CAD or BIM software so that engineers can immediately start working from a 3D model.

As data collection by drones is easily repeatable at low cost, images can be taken at regular intervals and overlaid on the original blueprints to assess whether the construction work is moving according to plan specifications.

2.8 Accurate of drone survey

The performance and type of drone, the quality of its components, the camera resolution, the height at which the drone flies, the vegetation, and the method and technology used to geolocate the aerial images can heavily influence the accuracy of drone survey mapping. At this point, it is possible to reach an absolute accuracy down to 1 cm (0.4 in) and 0.7 cm/px (0.3 in/px) GSD under optimal conditions with a high-end surveying drone such as the WingtraOne.

2.9 Drone survey procedure

1. Check before you leave the office

Check the local regulations and make sure that you are allowed to fly your drone at the planned location. Also, make sure that the weather is suitable, meaning no rain, fog, snowfall or strong winds. Check that the battery of your drone and connected devices such as tablets are fully charged and that the memory card of your drone camera has sufficient empty space to capture the entire project.

2. Plan your flight

You can create the survey flight plan with the drone flight planning app on the tablet. For this, just tap and drag the points around the area you want to survey, or import a KML file. Make sure you account for tall objects within the flight plan, as well as altitude differences. If needed, you can adjust flight settings such as altitude, ground sampling distance (GSD), flight direction and images overlap.

3. Set up your flight in the field

During this step, you basically unpack and assemble the drone and make sure that it is ready to take-off in safe conditions. Following the interactive check-list, you will one-by-one check every parameter, like the calibration of the airspeed sensor and making sure the camera lid is removed.

4. Fly and collect images

After pushing the take-off button, the drone autonomously takes off, captures images and lands back where it started. In this step, the operator essentially makes sure that nobody approaches the drone during take-off or landing and that the weather conditions stay optimal for the survey mission.

5. Geotag your images

After one or several flights, import the images into WingtraHub software to geotag them. Geotagging assigns geographical position (X, Y, Z) information to the images either in a separate CSV file or in the images' meta-data.

CHAPTER 3

PHOTOGRAMMETRY PROCESSING

3.1 Definition of Photogrammetry

Photogrammetry has been defined by the American Society for Photogrammetry and Remote Sensing as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded.

Photogrammetry literally means the act of deriving precise measurements from photographs. It involves taking a set of overlapping photos of an object, building, person, or environment, and converting them into a 3D model using a number of computer algorithms.

3.2 Agisoft Photo scan

Program description

Agisoft Metashape Professional is software that maximizes the possibilities of photogrammetry. It incorporates machine learning technologies for analysis and post-processing to deliver the highest accuracy results. Agisoft Metashape is a standalone software product that photogrammetrically processes digital images and generates 3D spatial data that can be used in geographic information system (GIS) applications, in cultural heritage documentation, for visual effects production, and for indirect measurements of objects of various scales.

Metashape makes it possible to:

process images obtained with RGB or multispectral cameras, including multi-camera systems.

convert photographs:

1-in to dense point clouds,

2-in to textured polygonal models,

3-in to georeferenced orthophoto maps,

4-in to digital elevation / terrain models (DEM / DTM).

Post-processing allows to remove shadows and texture distortions from the surface of models, calculate vegetation indices, compose prescription files for agricultural activities, automatically classify dense point clouds, etc.

The ability to export to all external post-processing packages makes Agisoft Metashape Professional a versatile photogrammetric tool.

Use Metashape for aerial photos:

- Point clouds
similar quality as laser scans
- Highly detailed
surfaces in TIN or GRID models
- Texturised 3D models
based on original images
- Orthophotos
With 2 cm precision

The core of Metashape is digital photogrammetry methods supported by modern computer vision algorithms.

Metashape knows what to offer to professionals. You can control the quality of the obtained results by using reports, fine-tune the workspace for specific tasks and use advanced features such as stereo mode or Python scripts.

A professional photogrammetric system can be easily operated by a novice: the intuitive interface is very easy to learn. You can get highly accurate results without even having specialized knowledge and training in photogrammetry.

3.3 Agisoft Works

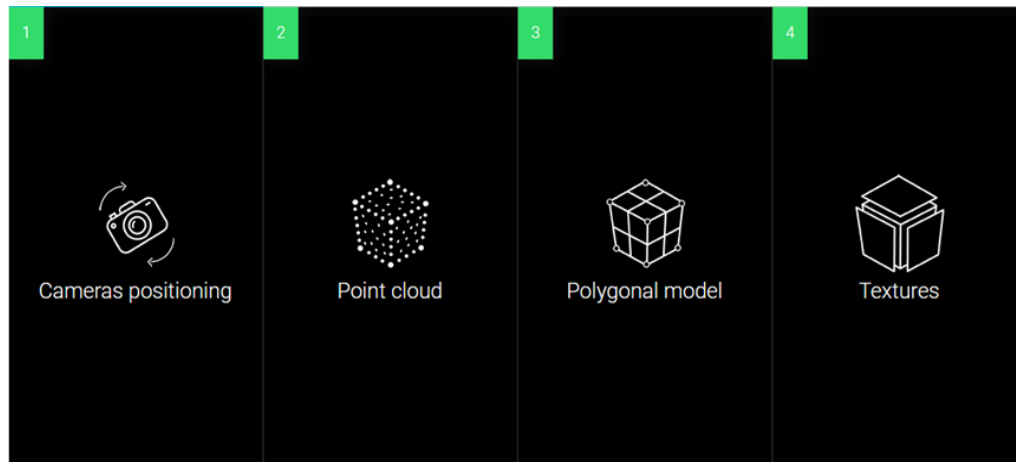


Figure 1-3.3 Agisoft Work

To find common points, Metashape uses an algorithm that first finds 'special' points in individual photographs. Then, on the basis of unique identifiers — descriptors — the points are identified. If a point is recognized in two or more frames, it becomes a match.

This is followed by frame alignment, or photo triangulation. This process is implemented with the use of the Bundle Block Adjustment algorithm, which is based on the least square's method. Bundle Block Adjustment is an interpretation of the Bundle Method, the most rigorous method for solving photo triangulation. The calculation can include the coordinates of the anchor points and the projection of markers on the frame. All parameters can be given weights — the scale of their participation in the calculation.

A dense cloud is built on the basis of depth maps. The Semi-Global Matching algorithm is used to create them. The essence of the algorithm is that for each pixel of the left image of a stereo pair there is a corresponding pixel on the right image. Each pixel in the left image is compared to a subset of pixels in the right image with the corresponding ordinate. Next, a parallelepiped is formed for the entire image, where one 'line' of cells corresponds to each pixel, and one longitudinal section of the cube corresponds to a row of pixels in the image. The elements of the cube are the values of the matching criterion, which are analyzed to find the minimum values for each pixel.

In addition, links between neighboring pixels in eight directions around a given pixel are analyzed. As a result, for each pixel of the left image, the corresponding value of the longitudinal parallax is found and, as a consequence, the spatial coordinates of the points of the dense model.

Some tips to ensure successful preparation of the 3D model:

- 1_If you can, maintain a perpendicular location relative to the object while you take photos.
- 2-Make sure that there are no moving objects in the background when you take the photos.
- 3-If you can, take photos in a location where lighting is consistent and doesn't cast shadows.

Agisoft photo scan.

Depending on which drone and camera you are using, the procedure in photo scan/ Metashape differs. Therefore, this instruction is divided in different sections depending on the function of each sensor/drone. The Agisoft manual is well written and give you a deeper understanding about the workflow described below.

The guide goes through how you create an ortho photo and 3D point cloud from images taken with a drone.

STEPS:

1-Import photos, location and accuracy.

2-Image quality.

Poor input, e. g. vague photos, can influence alignment results badly. To help you to exclude poorly focused images from processing Metashape suggests automatic image quality estimation feature.

Images with quality value of less than 0.5 units are recommended to be disabled and thus excluded from photogrammetric processing, providing that the rest of the photos cover the whole scene to be reconstructed. To disable a photo use, Disable button from the Photos pane toolbar.

Metashape estimates image quality for each input image. The value of the parameter is calculated based on the sharpness level of the most focused part of the picture.

3-Align photos.

In case some extra images should be subaligned to the set of already aligned images, you can benefit from incremental image alignment option.

To make it possible, two rules must be followed:

- 1) the scene environment should not have changed significantly (lighting conditions, etc.).
- 2) do not forget to switch on Keep key points option in the Preferences dialog, Advanced tab BEFORE the whole processing is started.

4-Ground control points (GCP).

Ground Control Points, or GCPs, are marked points on the ground that have a known geographic location. In aerial surveying, a drone can be used to autonomously collect photos of the survey area. If used, GCPs must be visible in these aerial photos. The photos are then processed in the cloud using drone mapping software. A common solution for collecting and processing drone data, used by many mapping professionals, is Drone Deploy.

Services like Drone Deploy create 2D orthomosaics, 3D models, digital elevation models (DEMs), and 3D point clouds from drone images. For aerial survey applications GCPs, are typically required as they can enhance the positioning and accuracy of the mapping outputs.

5-Dense point-cloud

Metashape allows to generate and visualize a dense point cloud model. Based on the estimated camera positions the program calculates depth information for each camera to be combined into a single dense point cloud.

Metashape tends to produce extra dense point clouds, which are of almost the same density, if not denser, as LIDAR point clouds.

A dense point cloud can be edited and classified within Metashape environment and used as a basis for such processing stages as Build Mesh, Build DEM, Build Tiled Model.

Alternatively, the point cloud can be exported to an external tool for further analysis.

6-Tiled Model

Hierarchical tiles format is a good solution for city scale modeling. It allows for responsive visualization of large area 3D models in high resolution. The tiled model can be either opened in Metashape itself or with Agisoft Viewer - a complementary tool included in Metashape installer package, or with some other external application which supports a hierarchical tiles format.

Tiled model is build based on dense point cloud, or mesh, or depth maps data. Hierarchical tiles are textured from the source imagery.

7-Digital Elevation Model

Metashape allows to generate and visualize a digital elevation model (DEM). A DEM represents a surface model as a regular grid of height values. DEM can be rasterized from a dense point cloud, a sparse point cloud or a mesh. Most accurate results are calculated based on dense point cloud data. Metashape enables to perform DEM-based point, distance, area, volume measurements as well as generate cross-sections for a part of the scene selected by the user. Additionally, contour lines can be calculated for the model and depicted either over DEM or Orthomosaics in Ortho view within Metashape environment.

8-Ortho Photo

Orthophoto export is normally used for generation of high-resolution imagery based on the source photos and reconstructed model. The most common application is aerial photographic survey data processing, but it may be also useful when a detailed view of the object is required. Metashape enables to perform orthophoto seamline editing for better visual results

EXPORTING ORTHO PHOTO

Place Markers

Markers are used to optimize camera positions and orientation data, which allows for better model reconstruction results. To generate accurately georeferenced orthophotos, control points (GCPs) should be distributed evenly within the area of interest, during our project we used 13 GCPs.

Figure 2-3.3 Ortho photo for study area

Figure 3-3.3 Distribution of control points and check point

Figure 4-3.3 Digital Elevation Model for study area

3.4 Digitizing

We have set points from dense cloud, which represent points for the street, trees, electricity poles, buildings and points distributed over the entire study area, and we have placed a break line in areas where there is a difference in altitude in order to make a topo map.

Figure 5-3.3 Topo map

CHAPTER 4

MONITORING OF BUILDINGS IN HEBRON

4.1 Overview of Hebron

A Palestinian city, and the center of Hebron Governorate. It is located in the West Bank, about 35 km south of Jerusalem, and is considered the largest Palestinian city in terms of population and area after Gaza City, with a population of approximately 200 thousand people, and an area of 42 km².

Hebron was known before that by different names, including the village of Arba, in relation to a Canaanite king named Arba, after which it was called Hebron. Hebron is famous for its grapes, in addition to the fact that its people are considered the most skilled merchants in Palestine.

4.2 Overview of the municipality of Hebron

Hebron Municipality is considered the largest institution in the city in terms of the volume of services it provides and the projects and works it carries out. That is why the Hebron Municipality is considered the main institution and force for the growth and development of Hebron.

The municipality of Hebron was affected by the difficult political conditions and continued to this day. Despite the difficulties, it continued to grow rapidly. This growth was reflected in the development of the city of Hebron in prosperity and development, in the level of services and in the development of the city's infrastructure. The number of employees in the municipality is now 1,200 employees.

Hebron Municipality provides distinguished services in several sectors, the most important of which are electricity, water, roads, sanitation, environmental preservation and buildings, in addition to various important services for the city, such as services directed to the industrial and agricultural sectors.

Hebron Municipality also provides a variety of cultural and sports services through the establishment and operation of specialized centers that deal with all segments of society.

Hebron Municipality is proud of the level it has reached today and the size of the great achievements that it was able to reach, while looking forward to more progress and giving and developing the city to reach the high level.

4.3 Buildings department

The building licensing activity is considered one of the most important activities carried out by the municipality, due to its general impact on many urban, economic, environmental, cultural and political aspects of the city and citizens.

Building department objectives:

The licensing of buildings and the collection of licensing fees is not a target of the building department as much as it is a way to achieve a number of goals.

As the primary goal of this department is to ensure the application of buildings and regulations, which were originally set to achieve the following goals:-

1. Preserving the organizational aspects of the city. One of the most important tasks of the building licensing activity is to ensure adherence to the pre-prepared Structural scheme for the city, and to maintain the approved divisions of the city into residential, commercial, industrial, agricultural and green areas, as well as potential expansion areas for the city borders .
2. Harmony of the urban aspect of the city: where the activity of buildings ensures the preservation of the architectural style of the neighborhoods and streets of the city, and the construction of buildings in a harmonious manner that preserves the aesthetic aspect of these neighborhoods and streets.
3. The safety of the environmental aspect of the city. Perhaps one of the most important goals of the building activity is the safety of the environment by separating industrial areas from residential ones, as well as ensuring legal setbacks and building percentages in residential, commercial and industrial areas.
4. Public safety for citizens, the Structural scheme for the main and secondary streets and preserving them from encroaching buildings, it contributes effectively to achieving road safety and reducing traffic accidents.
5. Economic aspects, preserving the laws of buildings and organization, avoids the city's waste of economic resources, by constructing many buildings randomly, which are built in a manner that violates the terms of organization and construction, and which can be removed before the end of their life.
6. The political aspects. The completion of the Structural scheme and defining the expansion areas for the municipal borders, and then expanding them, necessarily lead to confronting the settlement ambitions that surrounded the city and which are still threatened by further settlement expansion.
7. Cultural aspects Preserving the architectural style and the aesthetic aspect, as well as preserving the old historical architectural style, has a direct impact on the culture, sophistication and civilization of the city.

4.4 Inspection and monitoring - Department of Buildings

For more than thirty years, the Inspection Department has eight inspectors covering an area of 28 square kilometers.

Because of the importance of the Inspection Department at the work site, every time one of its employees is retired or transferred to another department, other employees are immediately employed, as five inspectors were employed in 1996, bringing the number to 8 inspectors, and in 2013, 4 new inspectors were employed, and in 2017 they were employed 4 new inspectors. In 2018, 4 new inspectors were hired.

The number of field inspectors has been reduced and most of them have been converted to office work, so that the current number of the Inspection Department is 6 inspectors only.

4.4.1 The mechanism of work of the Inspection and monitoring department

- The head of the Inspection department divides the geographic area of Hebron into several areas, and each employee of the inspectors receives the boundaries of a specific area to be responsible for it in the field.
- The employee monitors the violating buildings and the building encroachment on the streets or the neighbors and follows up the complaints received by the department.
- The employee inspects the site when changing the land features and excavation works, including deep and dangerous ones, and puts pressure on the owner to secure the site in terms of public safety procedures.
- After the owner completes the excavation work, the employee follows up on starting the foundation work to ensure that the owner is committed to the building line or the street boundary, according to the work on the site, in coordination with the surveying and planning departments if necessary. It is possible to accompany the surveying teams to the site as a result of the deep excavations, which require a device for Surveying, in which it is difficult to place the building line manually, or to bring the building line and the street boundary through the building permit file itself.
- After confirming the building line or the street boundary, if it is found to be in violation, an executive notice is given to the violator to stop working until he corrects his situation and adheres to what the municipality requires of him.
- When he continues to assault and violate, a letter is submitted to the governorate police to suspend him from work, by escorting the police to the site more than once, and the police make a pledge on the owner not to continue working and to review the municipality to correct his situation.

- The employee writes detailed reports attached to photos, a copy of the notification, and a police letter for dangerous and deep excavations, or submits reports to the governor of Hebron for sites outside the control of the Palestinian police.
- The Public Safety and Civil Defense Committee visit the site and write a report thereon.
- The employee transfers the necessary notifications and reports to the legal department to give a legal opinion in this regard, and they take the appropriate legal action.

4.4.2 The geographical area between the past and the present

In the past, the area of the geographical of Hebron that the inspectors covered was about 28 square kilometers, and there were 8 inspectors. After expanding the geographical borders of Hebron, it became 44 square kilometers, covering (124 parcels of lands) about three years ago, which increased inspection and follow-up of buildings, in addition to streets within Area C. Noting that after the expansion, only 6 inspectors remained.

Within the existing and available capabilities represented in the presence of 6 inspectors distributed in four areas occupying an area of 44 square kilometers, this constitutes a great pressure and burden on the inspectors, as the current stage is a stage of a large urban sprawl that differs from the past, as they currently own 3 motorcycles, but they are not sufficient to cover this large area. As a result of work pressure and the volume of tasks assigned to the inspector.



Figure 1-4.4.2 Hebron areas covered by the inspectors

4.4.3 The work of field inspectors & how to give Warnings and follow them up.

1. Dividing the boundaries of the municipality into sections.
2. Then an aerial photograph is taken for each region separately, and each inspector is assigned to a region.
3. Each observer is also given his own tools, which include the scale ruler and the Warnings book, in addition to the aerial photograph that contains the regions and parcel numbers.
4. The movement department in the municipality shall deliver the buildings inspector to his area, before receiving the motorbikes.
5. After receiving 4 motors, it is easy to reach the workshops and violations, notify them, and deal with them quickly
6. The inspector begins his work, and when there is any new building or any incorrect urban movement, the building inspector goes to this workshop and inquires about the license and the owner, and the building inspector determines the location through the aerial photograph, and also determines the region number and the parcel number
7. Here, the building inspector uses his tools to verify the necessary plans and information. If he does not obtain the necessary information, the Buildings Controller shall go to the municipality to obtain all the necessary and correct information.
8. In the event that there is no license or a violation of the conditions of the license, the buildings controller shall give an executive notice and specify a date for reviewing the buildings department in the municipality.
9. In the event of a clear encroachment on the building street line, setbacks, an increase in the number of floors, or the existence of a danger to pedestrians or neighbours, the Building observer shall prepare a letter for the city police, after the approval of the Head of the Buildings Department and the Legal Department, and then go directly to the police. Going to the place of work and stopping the work until the review of the buildings department in the municipality of Hebron
10. After issuing a warning for any building, the Building Controller follows up on this warning until the completion of all transactions
11. If licenses are found, the terms of the license and the agreed commitments shall be verified.
12. Excavation works are treated as construction by the necessity of having a prior permit in order to provide protection and safety for passers-by and workers
13. Office work: The Building Controller enters all notices on the computer and writes down all information related to the notice

4.4.4 How to deal with violations and remove them?

After confirming the existence of violations, the Building monitor writes an executive warning, and then the warning is transferred to the Head of the Buildings Department, who in turn approves its transfer to the Violations Removal Department within the municipality.

After taking all the legal and administrative procedures, the colleagues go to the Violations Removal Department with their tools and remove the violation.

4.5 Case study

Planning an urban building inspection with drones:

Drone Visual is a Brazilian company that sells drone solutions and software as an official Pix4D partner. They work on providing drone services as well as training to assist in drone inspections.

Recently, the Drone Visual team was contracted to inspect the facades of a tall building in Rio de Janeiro, Brazil. The main aim was to identify signs of wear in the structure, which would require a comprehensive analysis. The focus of the project was a fast turnaround with accurate results.

The team chose to use PIX4Dinspect, a specialized inspection platform designed to use AI and machine learning to automate and streamline inspection workflows. It has already been used to reduce the time required to inspect transmission towers by 60%, with more drone inspection success stories being replicated around the world. With this solution, Drone Visual would be able to share a 3D model with their client that the client could share and analyze with other colleagues easily.

The team from Drone Visual set out with a DJI Mavic 2 Zoom, which they flew around the building in several individual flights to gather data. A total of 504 images were captured, which covered a total area of 2,500 square meters. The flight time took a total of 1 hour and 30 minutes, which is far faster than any manual climb around the entirety of a building could take.

Project details	
Location	Rio de Janeiro
Company	Drone Visual
Software	PIX4Dinspect
Area of building surveyed	2500 meters ²
Images collected	504
Hardware used	DJI Mavic 2 Zoom
GSD	2 cm



Figure 2-4.5 Multi-storey building inspections

4.6 proposed monitoring system

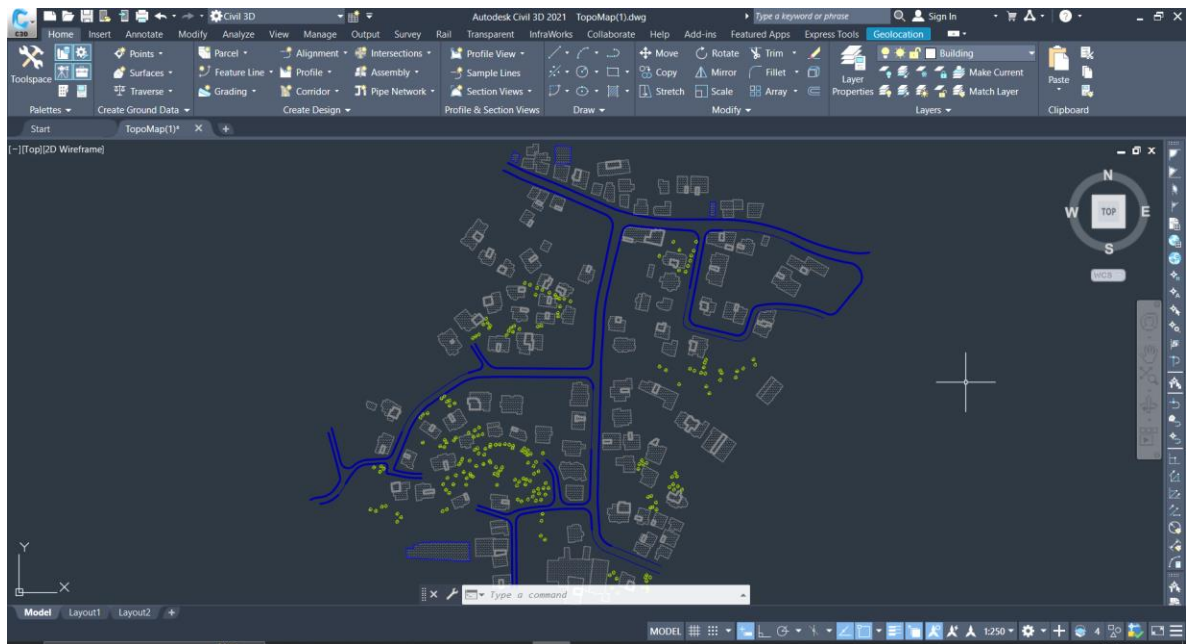
The idea of monitoring buildings using drones is initially based on photographing the area aerially, and then raising the area in 3D using the Agisoft program, and raising the buildings using the Arc Pro program in 3D, so that the number of floors appears in each building, and coloring the unlicensed floors in a distinctive color .

Inspection drones can greatly improve efficiency in several ways. First, they can provide accurate and detailed images and data of specific areas that are difficult to reach or potentially dangerous for human operators. This can include inspections of structures, taking measurements, and documenting changes to the ground.

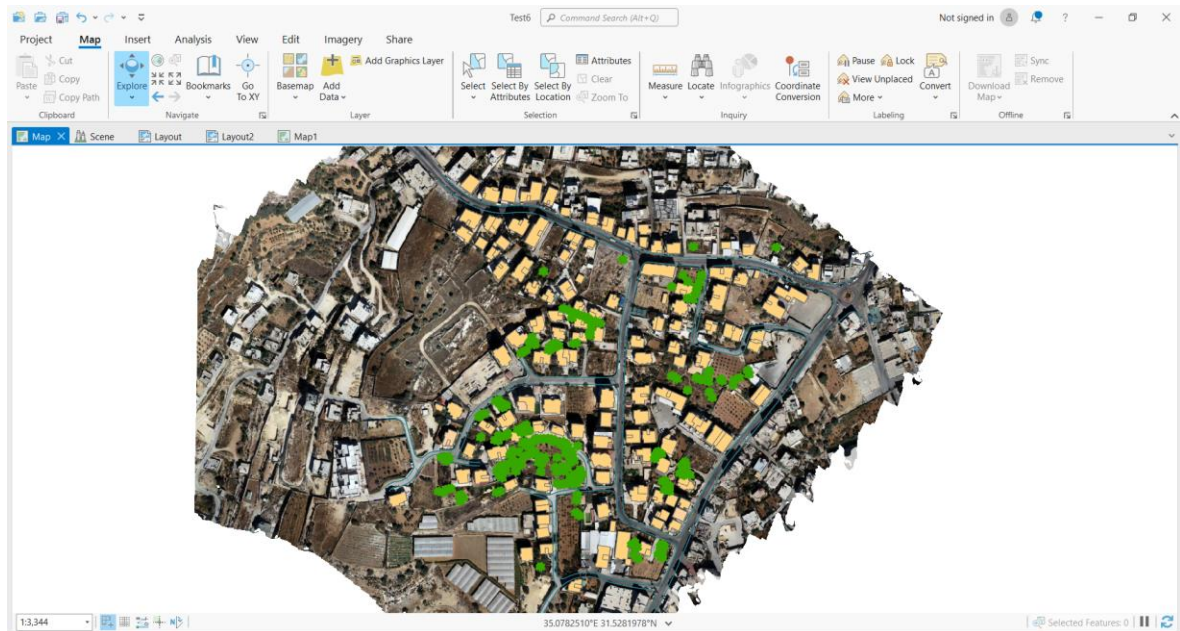
In addition, drones can allow workers to perform tasks in less time, reducing costs and increasing productivity. For example, drones can monitor buildings and provide updates, which can help crews make faster and more efficient decisions.

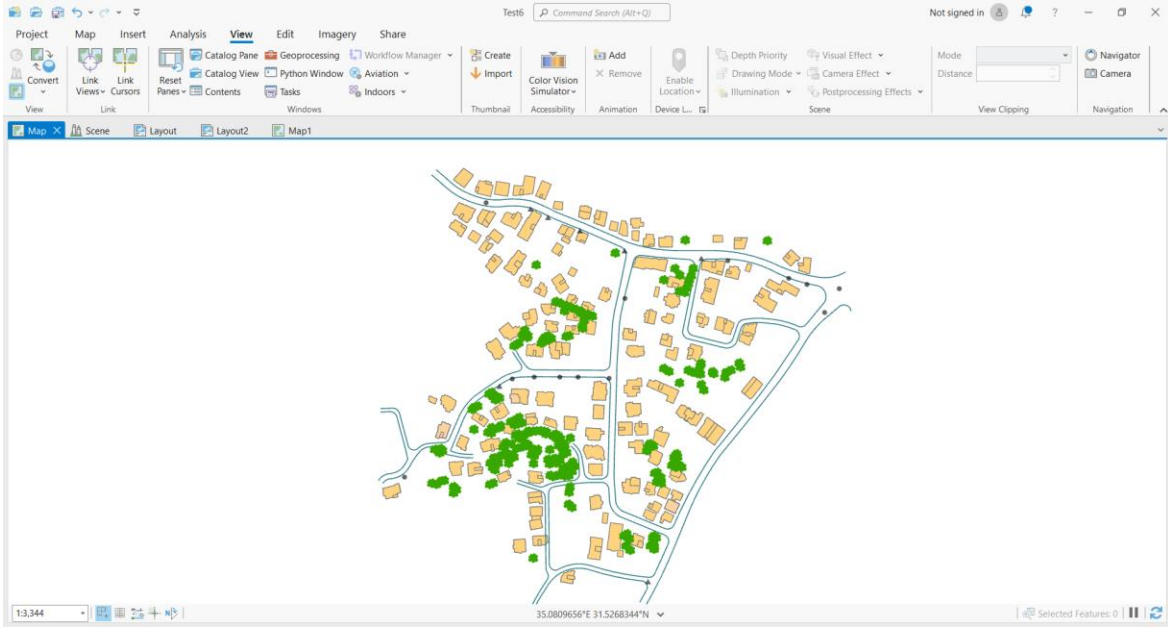
4.6.1 What are the action steps?

- After digitizing stage on Civil 3D, the layers (buildings, streets, trees and electricity poles) are exported to Arc Pro.

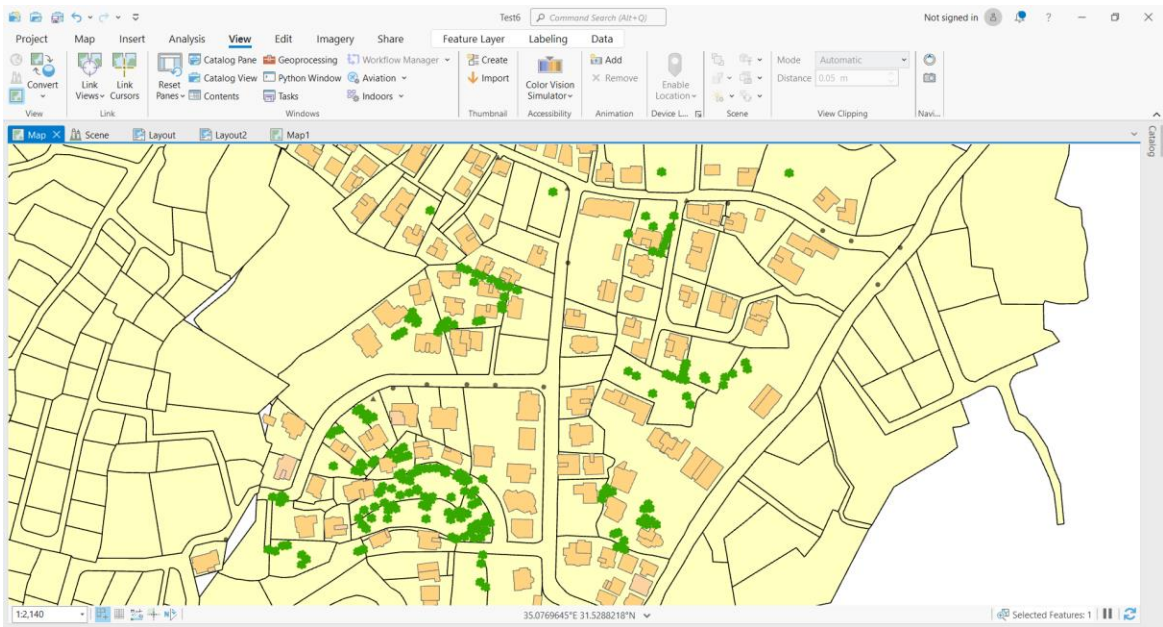


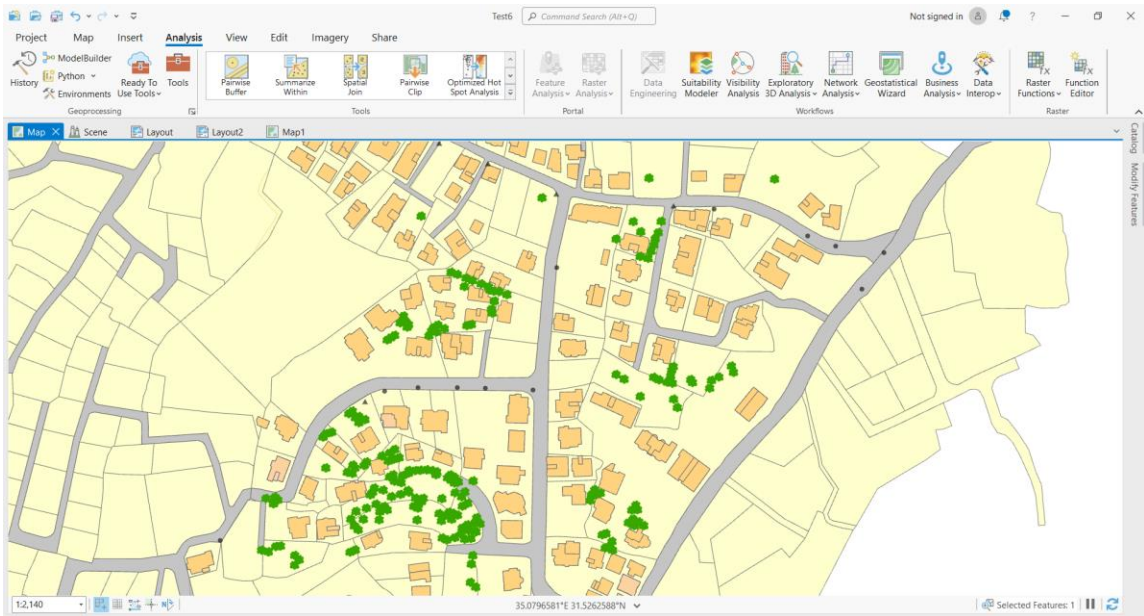
- The coordinates are defined in Arc Pro, where all the layers are in their correct location.



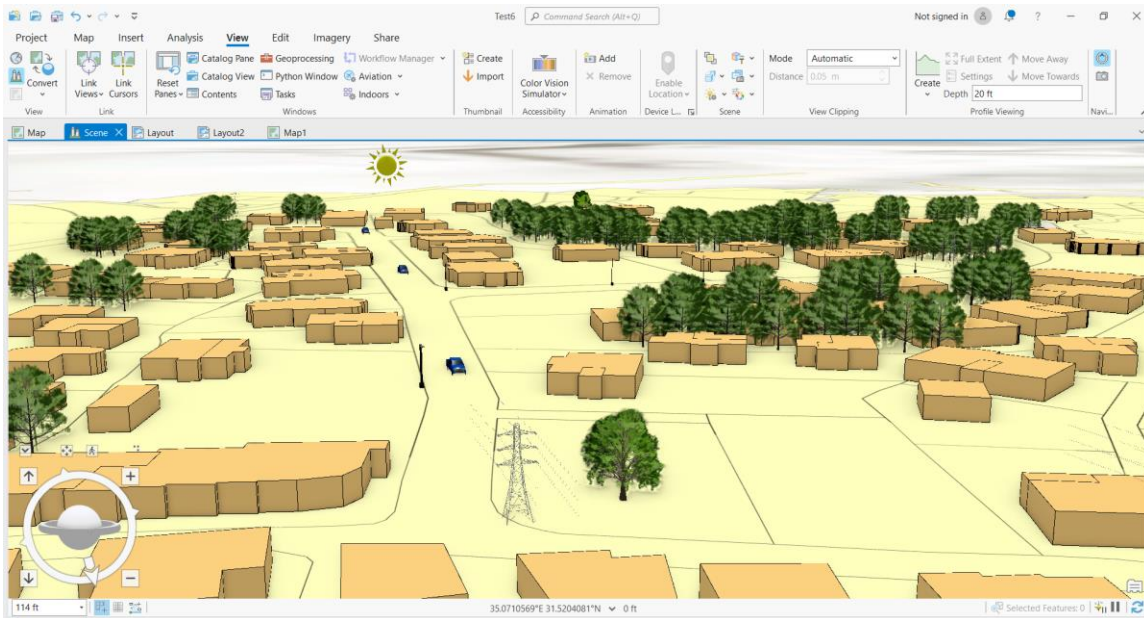


- Modification of parcels of appraisal lands for the area.

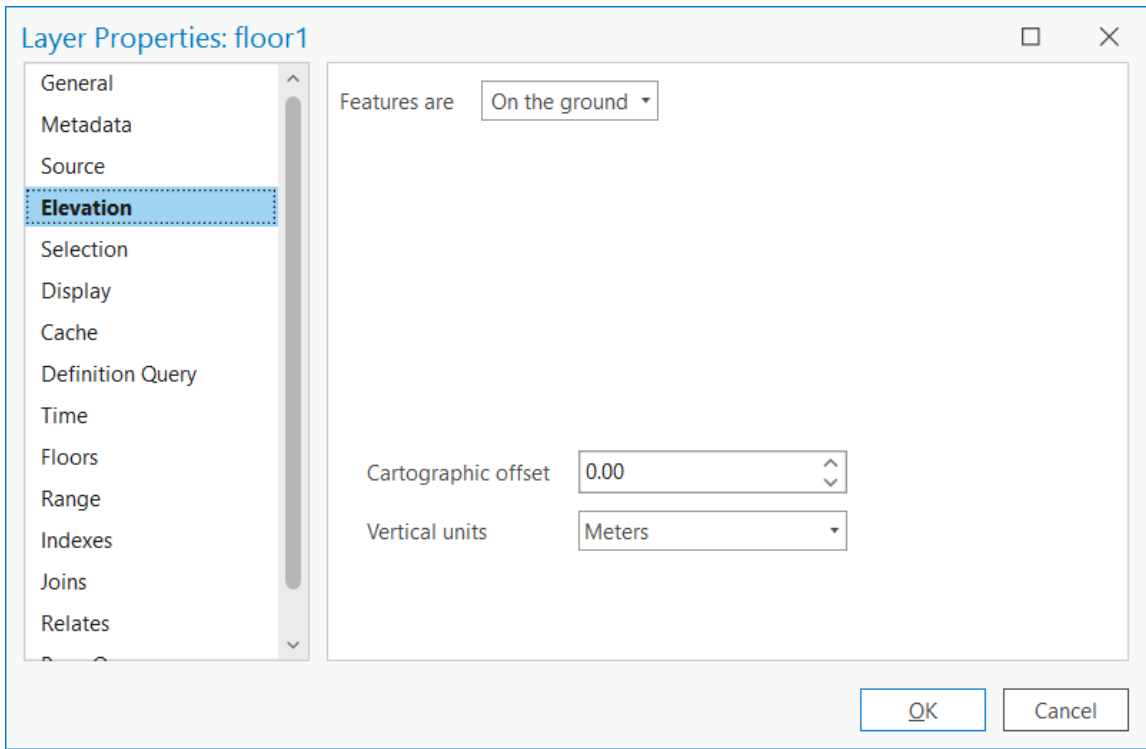




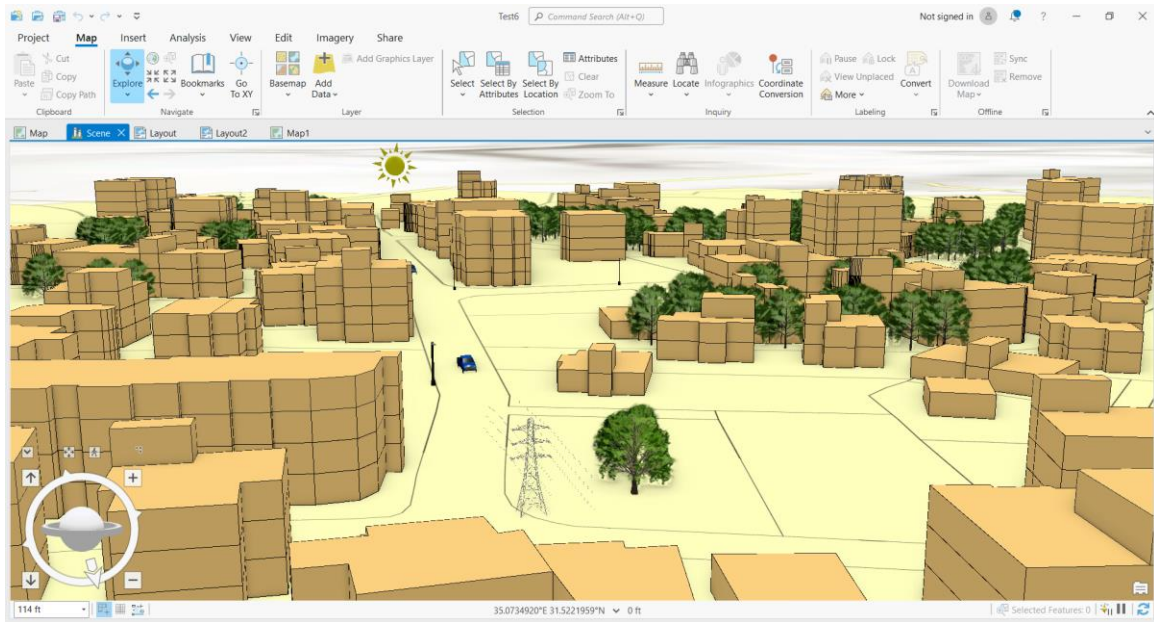
- Create a 3D model by converting layers from 2D to 3D.

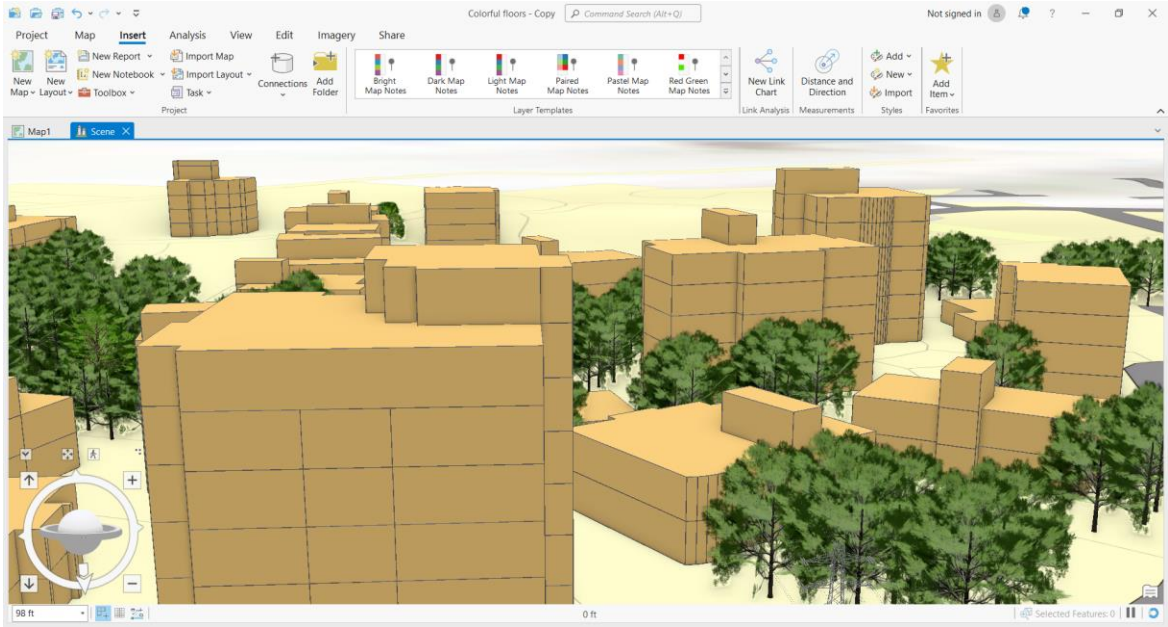


- A layer was made for each floor, and then the height of each floor was controlled from the ground through the characteristics of the layer (the height of one floor is 3 meters).

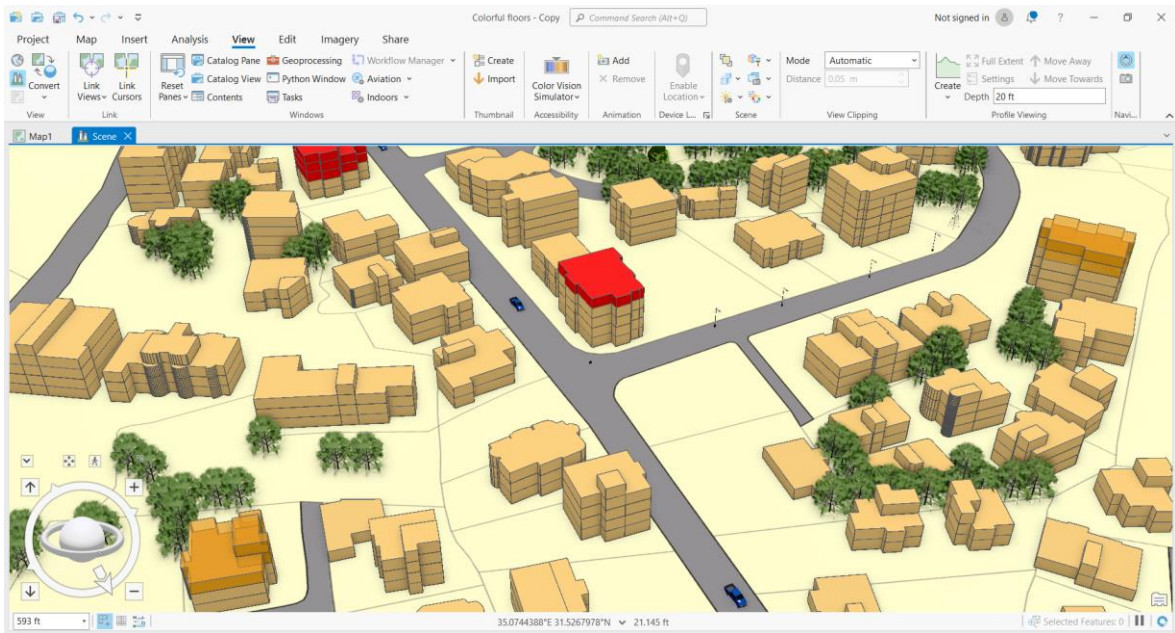


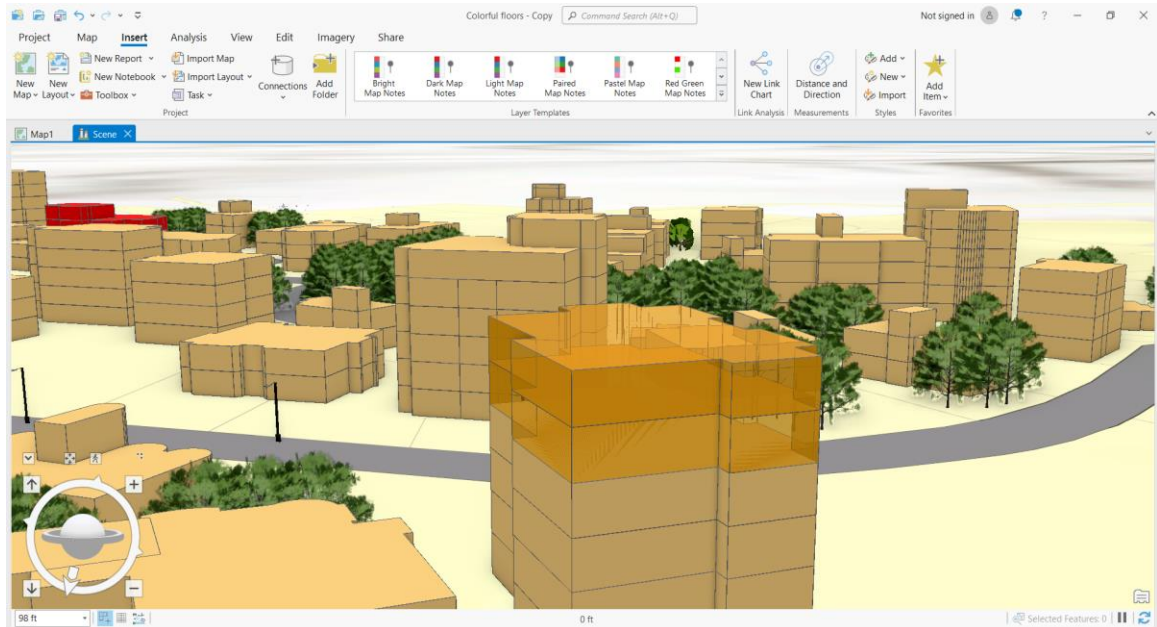
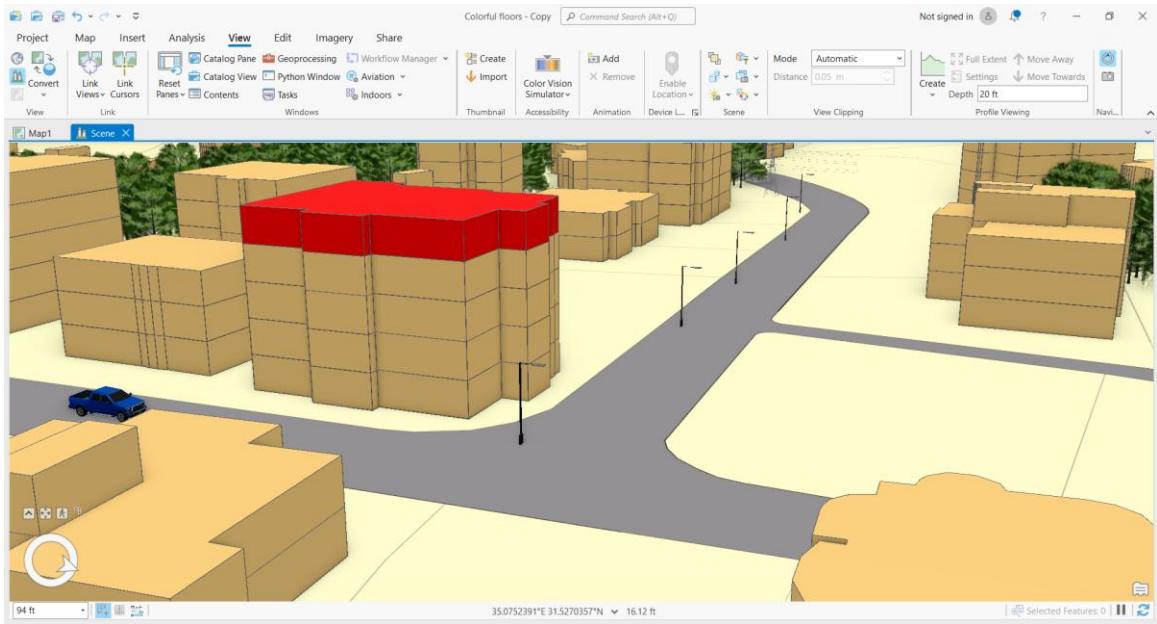
- Each building is shown according to its number of floors.





- Classification of floors according to the license:
 - Licensed and completed floors are shown in yellow.
 - Unlicensed and completed floors are shown in red.
 - Licensed and unbuilt floors are shown in orange.





4.6.2 What are the skills and requirements needed to operate an inspection drone?

To operate UAVs in building surveillance, it is essential to have a set of skills and requirements to ensure their safe and effective use.

- Basic technical knowledge of UAVs, their operation and remote control systems required. It is also important to know the rules and regulations governing their use.
- Drone piloting skills are also required to perform precise maneuvers and avoid accidents. It is important that you have good hand-eye coordination and the ability to operate the controls accurately.
- Inspection drone operators must be familiar with the terrain and work area to avoid potential obstacles and hazards. This includes knowing the location of power lines and any other obstructions that might interfere with the drone's flight.
- Drone operators must be prepared to detect and resolve issues that may arise during flight, such as loss of signal, and adverse weather conditions.

4.6.3 What are the regulations and licenses required to use drones?

The regulations and permits required for the use of drones in inspection vary by country and region of work. However, in general, the following regulations and requirements must be met:

- ✚ Drone Registration: In many countries, it is necessary to register the drone with a certain government agency before it can be used.
- ✚ Pilot's license: In some countries, it is necessary to obtain a drone pilot's license before operating a drone.
- ✚ Liability Insurance: It is important to have liability insurance to cover possible damages caused by the drone during use.
- ✚ Compliance with Civil Aviation Authority Regulations: In most countries, the Civil Aviation Authority (CAA) sets regulations for the commercial use of drones. These regulations include height and distance limits and exclusion zones.
- ✚ Flight permit: In some cases, a special flight permit is required to operate drones in specific areas, such as airports, restricted areas, or high-traffic areas.
- ✚ Respect for privacy: It is important to respect the privacy of individuals during drone operations and to comply with applicable laws and regulations in this field.

4.6.4 Traditional methods of monitoring buildings

Inspectors may also find it difficult to communicate clearly what they have seen with their own eyes to managers and stakeholders outside the site. Written notes do not provide the visual detail that you get when you are physically on site. Even when paired with images, it can be difficult to communicate the full picture.

Time consuming Large sites can take hours or several business days to accurately rate.

4.6.5 Benefits of drone surveillance

Drone flight offers a unique perspective that is both trustworthy and consistent. Flying a drone over the site provides an aerial view of the site and its progress. The result is a clear improvement over traditional methods of monitoring progress.

All drone data can be processed and organized into an easy to read report using the drone software. This eliminates the hours it would normally take to manually consolidate and organize all the information collected. Administrators can get updates in real time, reducing the time lag between when a change occurs on site and when it is actually detected.

Save time, Using a drone speeds up the site survey process, and also reduces labor costs.

Capture new drone images monthly or weekly, and share drone images with managers and site monitors.

Figure 3-4.6.1 Projection of buildings in two dimensions on the aerial image

Figure 4-4.6.1 The location of the buildings according to the parcels of land

Figure 5-4.6.1 Classification of buildings according to the license

CHAPTER 5

RESULTS AND RECOMMENDATIONS

5.1 Results

1. Drones make it easier than ever to automate the work of surveillance.
2. Periodic monitoring of areas through aerial photography, thus saving inspectors a lot of time and effort.
3. Achieving faster results in detecting violating buildings.
4. By using drones, the obstacles in the traditional system can be avoided.
5. Using the drone, we can see the site in 3D with all the details.

In Conclusion, drones are among the most prominent technologies in the field of civil engineering, and their use will increase over time, especially in the field of building monitoring, due to their efficiency in collecting accurate data without hindering any activities, which automatically leads engineers and municipalities to more confidence in working with drones.

5.2 Recommendations

This project will work to meet the needs of the Hebron Municipality, especially the monitoring department, which will help it solve the problem of shortage of inspectors compared to the large areas it is responsible for monitoring, as the use of a drone will speed up the site survey process, without burdening the budget with huge sums as a result:

1. The municipality adopts and implements this project.
2. Encourage the university to communicate with governmental and non-governmental agencies.
3. Developing the project so that it becomes a special application for monitoring buildings, so that anyone can use it and benefit from it.

APPENDIX A

Survey Report

Job name	Dahiat Al-Husain
Creation date	6 Oct 2022
Version	Trimble General Survey 3.21
Distance Units	Meters
Angle units	Degrees
Pressure Units	mbar
Temperature Units	Celsius

Coordinate system (Job)	
System	Palestine
Zone	Palastine New Grid B
Datum	Israel New Grid 7P B
Projection	
Projection	Transverse Mercator
Origin lat	31°44'03.81700"N
Origin long	35°12'16.26100"E
False northing	126907.390
False easting	169529.584
Scale	1.00000670
South azimuth (grid)	No
Grid coords	Increase North-East
Ellipsoid	Semi-major axis: 6378137.000 Flattening: 298.25722210

Local site	
Type	Grid
Datum transformation	
Type	Seven parameter
Semi-major axis	6378137.000
Flattening	298.257223
Rotation X	-0°00'00.3307"
Rotation Y	0°00'02.4158"
Rotation Z	-0°00'02.3519"
Translation X	105.678
Translation Y	-103.841

Translation Z	-110.044
Scale	2.55301ppm
Vertical adjustment	
Geoid file	ilum12

Collected Field Data (ECEF deltas: APC to APC)

Corrections	
South azimuth (grid)	No
Grid coords	Increase North-East
Magnetic declination	0°00'00"
Distances	Ground
Neighborhood adjustment	Off

Projection	
Projection	No projection
Ellipsoid	Semi-major axis: ? Flattening: ?

Local site	
Type	Grid

Datum transformation	
Type	None

Projection	
Projection	Transverse Mercator
Origin lat	31°44'03.81700"N
Origin long	35°12'16.26100"E
False northing	126907.390
False easting	169529.584
Scale	1.00000670
Ellipsoid	Semi-major axis: 6378137.000 Flattening: 298.2572210

Local site	
Type	Grid

Datum transformation	
Type	Seven parameter
Semi-major axis	6378137.000
Flattening	298.257223

Rotation X	-0°00'00.3307"
Rotation Y	0°00'02.4158"
Rotation Z	-0°00'02.3519"
Translation X	105.678
Translation Y	-103.841
Translation Z	-110.044
Scale	2.55301ppm

Vertical adjustment

Geoid file	ilum12
-------------------	--------

Coordinate system

System	Palestine
Zone	Palastine New Grid B
Datum	Israel New Grid 7P B

Corrections

South azimuth (grid)	No
Grid coords	Increase North-East
Magnetic declination	0°00'00"
Distances	Grid
Neighborhood adjustment	Off

Rover options

Elevation mask	10	PDOP mask	6						
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Rover options

Elevation mask	10	PDOP mask	6						
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Survey event

Survey event	Rover started
---------------------	---------------

Point	RTCM0002	Latitude	31°30'27.66877"N	Longitude	35°01'48.45270"E	Height	888.921	Code	
--------------	----------	-----------------	------------------	------------------	------------------	---------------	---------	-------------	--

GNSS receiver

Receiver type	Unknown
Serial number	
Firmware version	0
Antenna type	AdV Null Antenna

Measurement method	Antenna Phase Center
Tape adjustment	0.000
Horizontal offset	0.000
Vertical offset	0.000

Base point									
Point	RTCM0002	Antenna height	0.000	Type	Corrected				

GNSS receiver	
Receiver type	Unknown
Serial number	
Firmware version	0
Antenna type	AdV Null Antenna
Measurement method	Antenna Phase Center
Tape adjustment	0.000
Horizontal offset	0.000
Vertical offset	0.000

Base point									
Point	RTCM0002	Antenna height	0.000	Type	Corrected				

Initialization event: Gained									
GPS week	2230	Seconds	388050	Initialization type	On the fly	Survey type	Real-time	Initialization count	0

GNSS receiver	
Receiver type	SP60
Serial number	6014500047
Firmware version	4.21
Antenna type	SP60
Measurement method	Bottom of antenna mount
Tape adjustment	0.000
Horizontal offset	0.000
Vertical offset	0.069

Point	1	ΔX	-3389.253	ΔY	2701.210	ΔZ	2130.291	Code	cp
--------------	---	-----------	-----------	-----------	----------	-----------	----------	-------------	----

		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	H_z Prec	0.011	V_t Prec	0.029		
QC 1		Satellites	12	PDOP	1.5	HDOP	0.6	VDOP	1.4
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	388160	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
-----------------	------	----------------	--------	----------------------------	------------	--------------------	-----------	-----------------------------	---

Initialization event: Gained

GPS week	2230	Seconds	388266	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
-----------------	------	----------------	--------	----------------------------	------------	--------------------	-----------	-----------------------------	---

Point	2	ΔX	-3458.797	ΔY	2927.633	ΔZ	2061.843	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	H_z Prec	0.012	V_t Prec	0.025		
QC 1		Satellites	13	PDOP	1.2	HDOP	0.5	VDOP	1.1
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	388304	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	388309	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Lost

GPS week	2230	Seconds	388312	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	388491	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	3	ΔX	-3505.911	ΔY	2918.958	ΔZ	2120.561	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	H_z Prec	0.006	V_t Prec	0.014		

QC 1		Satellites	11	PDOP	1.2	HDOP	0.5	VDOP	1.1
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	388536	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	388732	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	4	ΔX	-3542.982	ΔY	3066.368	ΔZ	2048.956	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.010	Vt Prec	0.020		
QC 1		Satellites	13	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	388805	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	388866	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	5	ΔX	-3523.640	ΔY	3086.391	ΔZ	1995.857	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.027		
QC 1		Satellites	11	PDOP	1.3	HDOP	0.6	VDOP	1.2
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	388916	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	388977	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	6	ΔX	-3499.105	ΔY	2997.135	ΔZ	2056.770	Code	cp
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		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.014	Vt Prec	0.026		
QC 1		Satellites	15	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389025	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389106	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	7	ΔX	-3339.002	ΔY	2863.470	ΔZ	1941.180	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.014	Vt Prec	0.030		
QC 1		Satellites	11	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389141	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389195	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	8	ΔX	-3394.728	ΔY	2947.020	ΔZ	1942.961	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.011	Vt Prec	0.022		
QC 1		Satellites	12	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389221	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389291	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	9	ΔX	-3354.553	ΔY	3058.463	ΔZ	1773.637	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.024		
QC 1		Satellites	13	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389332	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389478	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	10	ΔX	-3295.278	ΔY	2995.851	ΔZ	1735.377	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.013	Vt Prec	0.025		
QC 1		Satellites	14	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389502	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389705	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	11	ΔX	-3513.697	ΔY	3113.049	ΔZ	1950.572	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.028	Vt Prec	0.053		
QC 1		Satellites	14	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389724	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	389795	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	12	ΔX	-3568.040	ΔY	3114.494	ΔZ	2031.319	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.013	Vt Prec	0.025		
QC 1		Satellites	14	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	389870	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390004	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	13	ΔX	-3332.783	ΔY	2996.762	ΔZ	1798.646	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.023		
QC 1		Satellites	12	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390016	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390023	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Lost

GPS week	2230	Seconds	390026	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390120	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	14	ΔX	-3329.787	ΔY	2952.105	ΔZ	1830.137	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.024		
QC 1		Satellites	13	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390135	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390301	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Lost

GPS week	2230	Seconds	390314	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390315	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	15	ΔX	-3286.271	ΔY	2824.999	ΔZ	1897.035	Code	cp
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.015	Vt Prec	0.029		
QC 1		Satellites	15	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390332	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390480	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	16	ΔX	-3420.659	ΔY	2936.023	ΔZ	1995.868	Code	ch p
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		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.010	Vt Prec	0.017		
QC 1		Satellites	13	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390491	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390505	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Lost

GPS week	2230	Seconds	390508	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390668	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	17	ΔX	-3432.970	ΔY	2839.255	ΔZ	2091.855	Code	ch p
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.024		
QC 1		Satellites	13	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390716	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390827	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	18	ΔX	-3515.441	ΔY	2905.301	ΔZ	2133.599	Code	ch p
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.012	Vt Prec	0.021		

QC 1		Satellites	14	PDOP	1.1	HDOP	0.5	VDOP	1.0
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390875	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390886	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Point	100	ΔX	-3507.477	ΔY	2917.851	ΔZ	2119.400	Code	le
		Method	Fixed	Type	Rapid point	Search class	Normal		
Antenna height	1.530	Type	Uncorrected	Hz Prec	0.014	Vt Prec	0.025		
QC 1		Satellites	12	PDOP	1.0	HDOP	0.5	VDOP	0.9
		Base data age	1	RMS	?	Positions used	1		

Initialization event: Lost

GPS week	2230	Seconds	390901	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Gained

GPS week	2230	Seconds	390910	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Initialization event: Lost

GPS week	2230	Seconds	390916	Initialization type	On the fly	Survey type	Real-time	Initialization count	0
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Survey event

Survey event	End survey
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Reduced points

Point	RTCM0002	North	101742.141	East	152897.502	Elevation	869.603	Code	
Point	1	North	104191.503	East	157058.180	Elevation	938.739	Code	cp
Point	2	North	104094.630	East	157283.304	Elevation	965.334	Code	cp
Point	3	North	104167.416	East	157303.362	Elevation	958.922	Code	cp

Point	4	North	104077.795	East	157445.179	Elevation	967.825	Code	cp
Point	5	North	104018.242	East	157450.380	Elevation	963.361	Code	cp
Point	6	North	104086.577	East	157363.327	Elevation	968.606	Code	cp
Point	7	North	103959.955	East	157161.811	Elevation	954.385	Code	cp
Point	8	North	103960.096	East	157262.198	Elevation	957.365	Code	cp
Point	9	North	103765.033	East	157330.076	Elevation	951.449	Code	cp
Point	10	North	103725.974	East	157244.738	Elevation	942.127	Code	cp
Point	11	North	103967.364	East	157466.421	Elevation	959.677	Code	cp
Point	12	North	104058.962	East	157498.935	Elevation	964.696	Code	cp
Point	13	North	103795.644	East	157267.114	Elevation	949.488	Code	cp
Point	14	North	103834.663	East	157228.897	Elevation	946.169	Code	cp
Point	15	North	103911.399	East	157099.975	Elevation	949.247	Code	cp
Point	16	North	104019.579	East	157268.168	Elevation	961.552	Code	ch p
Point	17	North	104135.813	East	157196.194	Elevation	955.756	Code	ch p
Point	18	North	104186.715	East	157297.684	Elevation	952.401	Code	ch p
Point	100	North	104167.429	East	157303.356	Elevation	956.679	Code	le

APPENDIX B

Agisoft Metashape Processing Report 23 December 2022



Survey Data

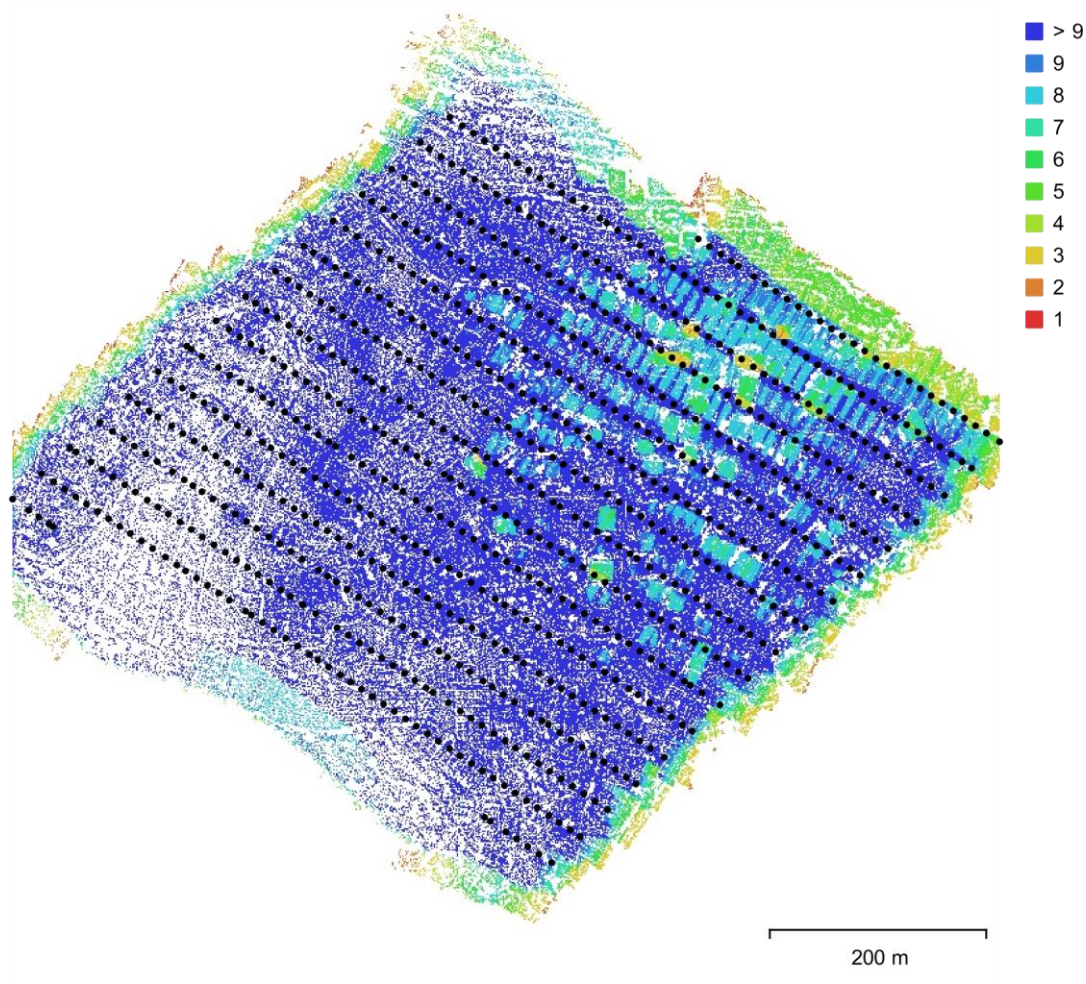


Fig. 1. Camera locations and image overlap.

Number of images: 770	Camera stations: 770
Flying altitude: 77.4 m	Tie points: 574,247
Ground resolution: 2.28 cm/pix	Projections: 2,798,333
Coverage area: 0.265 km ²	Reprojection error: 0.699 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC6310S (8.8mm)	5472 x 3648	8.8 mm	2.41 x 2.41 µm	No

Table 1. Cameras.

Camera Calibration

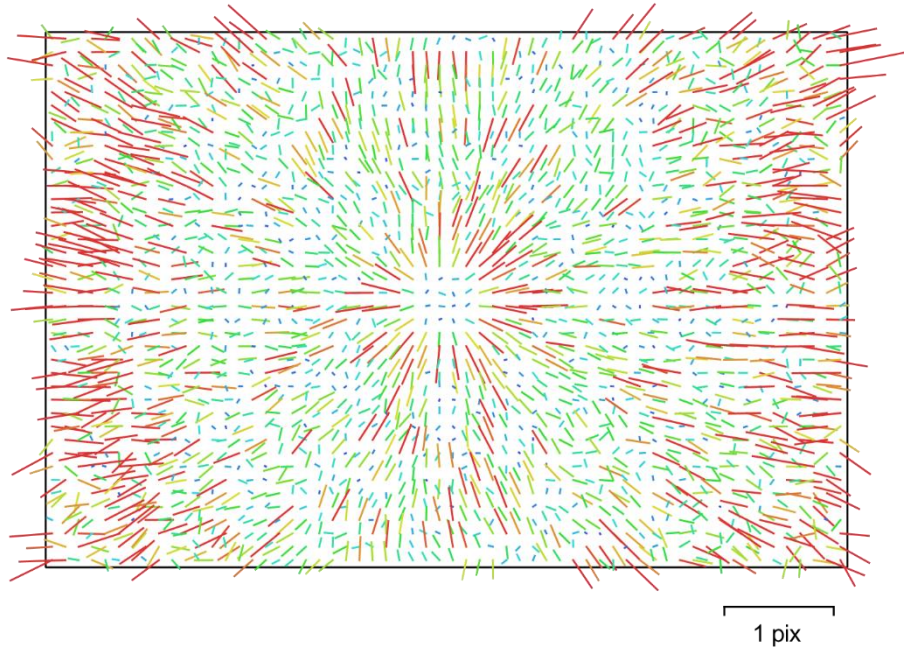


Fig. 2. Image residuals for FC6310S (8.8mm).

FC6310S (8.8mm)

770 images

Type
Frame

Resolution
5472 x 3648

Focal Length
8.8 mm

Pixel Size
2.41 x 2.41 μm

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	3398.42	1	1.00	0.78	0.84	-0.48	0.03	0.20	-0.10	-0.34
C_x	-4.63933	0.029		1.00	0.67	-0.37	0.01	0.17	0.32	-0.27
C_y	-19.1469	0.027			1.00	-0.40	0.02	0.18	-0.08	0.01
K₁	-0.0100839	2.3e-05				1.00	-0.83	0.66	0.06	0.17
K₂	0.000741643	4.8e-05					1.00	-0.96	-0.01	-0.00
K₃	0.00449015	3.6e-05						1.00	-0.02	-0.08
P1	-0.00018892	1.6e-06							1.00	0.05
P2	-0.00124876	1.3e-06								1.00

Table 2. Calibration coefficients and correlation matrix.

Camera Locations

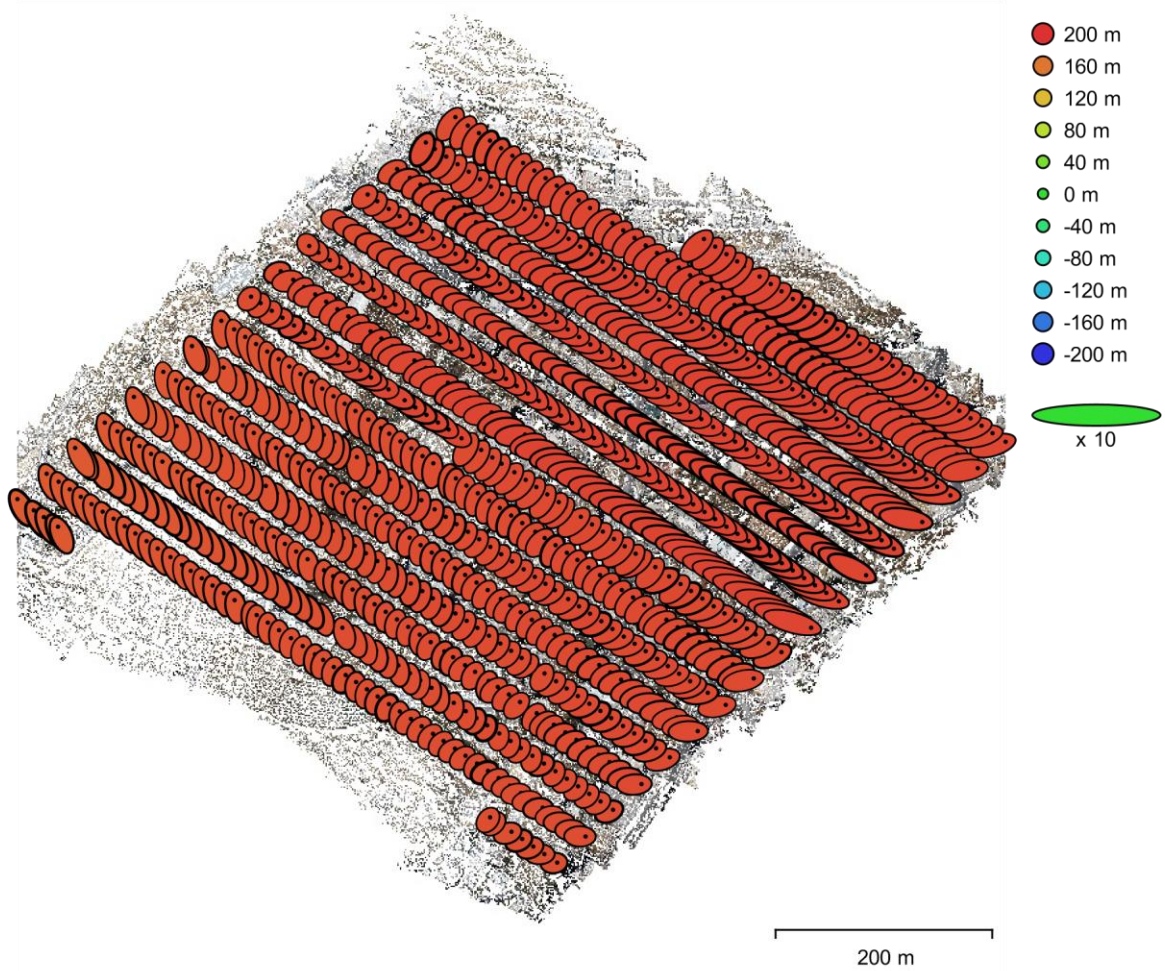


Fig. 3. Camera locations and error estimates.

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)
1.31283	0.916084	186.208	1.60085	186.215

Table 3. Average camera location error.

X - Easting, Y - Northing, Z - Altitude.

Digital Elevation Model

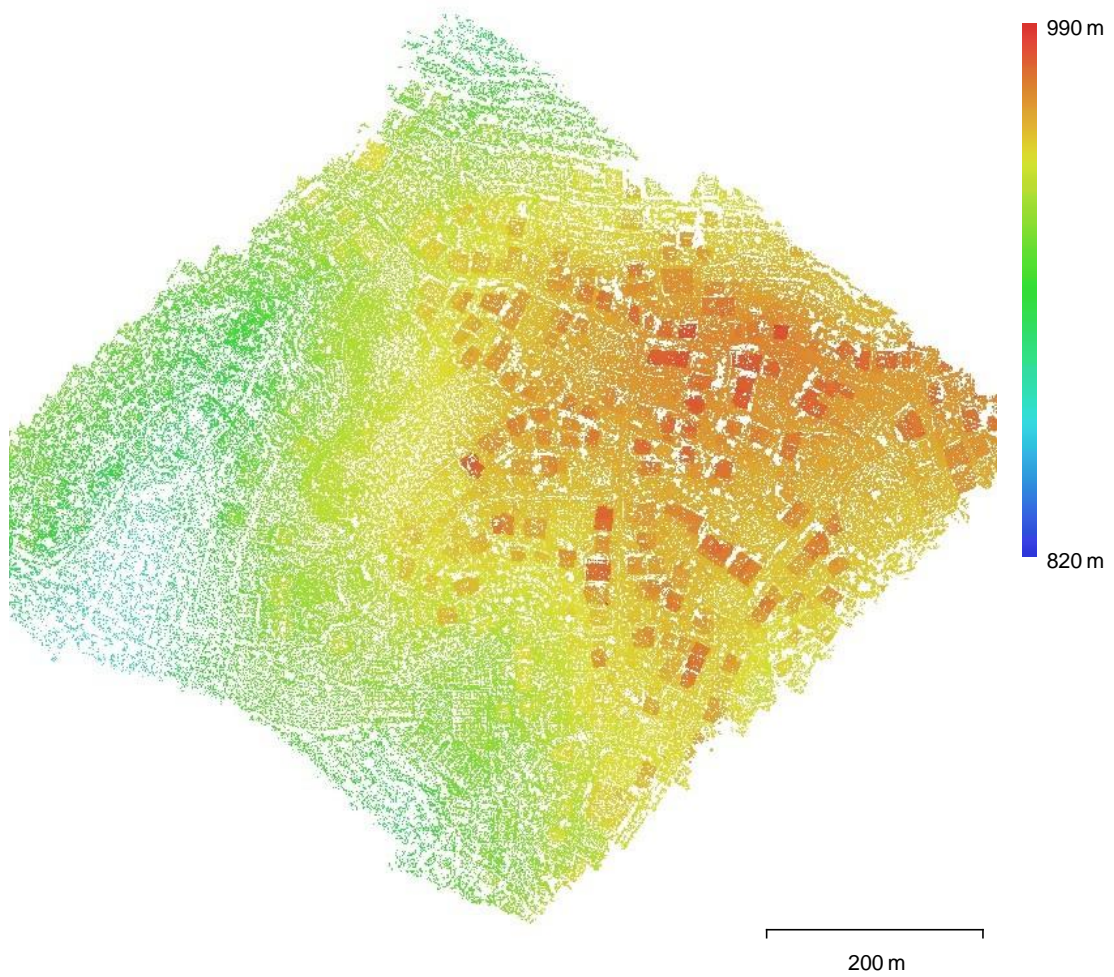


Fig. 4. Reconstructed digital elevation model.

Resolution: unknown
Point density: unknown

Processing Parameters

General	
Cameras	770
Aligned cameras	770
Markers	13
Frames	2
Coordinate system	Palestine 1923 / Palestine Grid (EPSG::28191)

Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	574,247 of 642,537
RMS reprojection error	0.198383 (0.69895 pix)
Max reprojection error	0.595517 (46.3408 pix)
Mean key point size	3.12394 pix
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	5.24712
Alignment parameters	
Accuracy	High
Generic preselection	Yes
Reference preselection	Source
Key point limit	40,000
Tie point limit	4,000
Guided image matching	No
Adaptive camera model fitting	No
Matching time	14 minutes 59 seconds
Matching memory usage	760.04 MB
Alignment time	19 minutes 25 seconds
Alignment memory usage	271.87 MB
Software version	1.7.0.11429
File size	66.53 MB
System	
Software name	Agisoft Metashape Professional
Software version	1.7.0 build 11429
OS	Windows 64 bit
RAM	15.78 GB
CPU	Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
GPU(s)	NVIDIA GeForce GTX 1650 Ti

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