KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

A PROJECT REPORT ON

PREPARATION OF TOPOGRAPHICAL MAP OUTSIDE KATHMANDU UNIVERSITY PREMESIS USING AERIAL IMAGES PRODUCED BY UAV

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Sincerely,
Rishav Khatiwada

Abstract

The main focus of this study is on the potential and application of UAV photogrammetry in the creation of topographic maps. Pix4Dmapper software was used to process the digital images in order to create digital surface models and orthophotos. The report describes how Pix4D and GIS technologies were used to create a topographical map for an area that shows the elevation change of 20m (1472m to 1492 m). The map shows a varied terrain with a strong agricultural component that is woven together with a variety of features like buildings, roads, canals, vegetation, transmission lines, and bare ground. The report gives us idea about how precise and comprehensive topographical maps can be created using UAVs, Pix4D software, and GIS, facilitating better understanding and well-informed decision-making for the region under study.

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LIST OF ABBREVIATIONS

GIS	Geographical Information System
UAV	Unmanned Aerial Vehicles
GCP	Ground Control Points
UAS	Unmanned Aerial Systems
DSM	Digital Surface Model
DEM	Digital Elevation Model
DTM	Digital Terrain Model
GNSS	Global Navigation Satellite System
RAM	Random Access Memory

1 INTRODUCTION

1.1. Background

Topographic map is a detailed and accurate graphic representation of cultural and natural features on the ground such as streams lakes, dams, swamps, roads and tracks, buildings, vegetation, defense and forestry reserves. The important in generation topographic maps are information contents, geometric accuracy and contour map(Azmi et al., 2014a). Photogrammetry techniques become easier, faster and cheaper now due to technological developments for mapping. Development in digital technology has increased the reliability of the data captured by the camera and used to be the actual data(Ahmad et al., 2018a). With the ability of UAV in providing higher resolution imageries and more accurate positioning than the satellite image, the topographic survey work in collecting data becomes faster. The other advantages of UAV are it is easy to operate, the image has no cloud obstacle, it has a clear detail and high resolution, cost of production is low, and one of the most preferred for topographic mapping in engineering survey (Muhammad & Tahar, 2021).

Traditionally, surveyor acquired the topography data by using conventional method (tachymetry) to produced detailed plan. The horizontal control requires traverse to be established on the site and vertical control need to be observed from known height point. But even this technique seems involved lower cost, this old fashion method slows the pace of ground data acquisition. To speed up the process from ground survey to final products, it’s required more cost (money, time, and effort). For instance, by using Terrestrial Laser Scanner, millions of point cloud can be generated in a single session. However, this technique required long survey sessions, powerful computer processor and well-trained personnel to operates and process the large data. Alternatively, point cloud can be generated from image-based method such digital photogrammetry. This data can be obtained either using close range or aerial photogrammetry. For topographical mapping, aerial photogrammetry method can cover a large area but not practical for a small area. Thus, with the rapid development and exponential growth of Unmanned Aerial Vehicles (UAV) seems an ideal platform for mapping small area topography for detail plan production.(Zainuddin et al., 2015)

The aircraft can navigate without a human pilot onboard. A small format digital camera can be mounted to this aircraft with other required accessories to obtain digital images geometrically described. This platform offers several flight modes such as manual, semi-automated or fully automated modes of operation. Images captured are processed using photogrammetric software, Pix4Dmapper software used for image processing; the software automatically converts images taken by UAV to precise geo-referenced orthophotos and 3D models(Ismael & Henari, 2019). Pix4D programs use still images of stationary objects to generate point clouds, 3D models and orthophotomaps. It is widely used in aviation and engineering photogrammetry, computer animations and remote sensing. With the ability to export processed data to a variety of formats, this application is compatible with graphical programs (such as Autocad) or GIS analysis software (such as ArcGis) (Barbasiewicz et al., n.d.). The report aims to find the potential of employing UAV for large scale topographic mapping outside Kathmandu University permises.

1.1 UAV

Unmanned Aerial Vehicles or UAV refers to an aircraft without an on-board human pilot. UAVs can be remotely controlled aircraft which is flown by a pilot at a ground station or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. Moreover, UAV is often used in military but now UAV is also used in civil purpose such as mapping, facility management, construction and industrial applications. UAV has low manufacturing and operational cost of the systems, the flexibility of the aircraft to adjust according to user requirements and the elimination of the risk of pilots in difficult missions. The continuous trend in the miniaturisation of electronics enables the production of smaller UAV while simultaneously equipping them with cameras and other sensors to support aerial geo-data collection.(Azmi et al., 2014a)

1.2 Orthophoto

An orthophotograph is a vertical photograph or mosaic which displays images of objects in true planimetric (horizontal) position. This planimetric accuracy allows interpreters to use orthophotos like maps for making direct measurements of geographic location, distances, angles, and area. On unrectified aerial photography such measurements can only be approximate because of image displacement and scale change caused by variations in local relief. The orthophoto rectification process essentially flattens the local relief to a common uniform scale. When an orthophoto is printed in register with controlled map elements the composite becomes an orthophotomap that is extremely accurate in terms of equivalence and conformality for small areas on the earth's all-sidecurving surface. The orthophotomap, therefore, represents the same wealth of detail found on a conventional vertical aerial photograph with the planimetric accuracy of a topographic line map.(Thrower & Jensen, 1976)

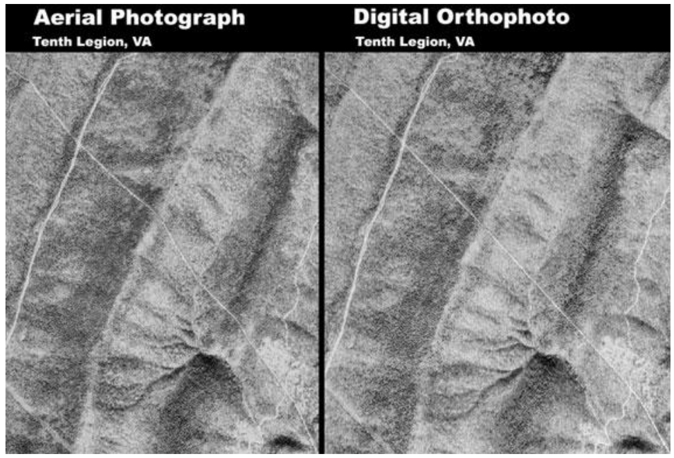

Figure 1: Aerial Photo vs Orthophoto

Source: usgs.gov/media/images/aerial-photograph-vs-orthoimage

1.3 GCP

Multiple photogrammetry applications are based on UAS due to cost efficient data acquisition and high spatio-temporal resolution imagery. Widely used in various fields like land surveying and construction, GCPs can greatly increase the accuracy of the 3D information and their measurement is an important aspect of georeferencing the UAS image blocks. Ground control points are used in the process of indirect georeferencing the UAS images, a minimum of three ground control points being required, although increasing the number of GCPs will lead to higher accuracy of the final results i.e., point cloud, 3D mesh, orthomosaic DSM. Moreover, exceeding the number of ground control points is a time-consuming process, both in the field and computationally.(Oniga et al., 2018)

1.4 Problem Statement

There are several hurdles to overcome when integrating Pix4D, GIS, and UAVs for terrain mapping. The main challenge is the smooth transfer of the various types of data collected by the drone to the GIS environment. This requires standardized workflows to ensure accuracy and interoperability. Additionally, integrating Pix4D software with a GIS platform requires careful migration planning. Achieving the highest level of accuracy in terrain mapping with drones requires overcoming barriers to deploying strategic GCPs and continuous monitoring during the flight to resolve unforeseen problems. To realize the full potential of this integrated approach, delivering more accurate, faster and more affordable solutions for geospatial mapping applications, these obstacles must be overcome.

1.5 Objective

primary objective:

To create a high-resolution and accurate topographical map of land outside Kathmandu University premises using UAV imagery processed in Pix4d and integrated into a GIS environment.

Secondary Objective:

- To analyze the terrain characteristics of the area.
- To develop a workflow for processing UAV imagery in Pix4d and integrating it into a GIS environment for future projects
- To create a visually appealing and informative topographical map suitable for surveyors.

1.6 Scope

This report outlines the process for producing a high-resolution topographical map using UAVs, Pix4d software, and GIS. We first detail the essential stages of data acquisition, including flight planning, image capture, and ground control point setup. Next, we delve into the data processing steps within Pix4d, covering image preprocessing, photogrammetric reconstruction, and generation of both orthomosaic images and digital DEMs. Finally, we explore the integration of the processed data into a GIS environment, encompassing georeferencing, analysis of topographical features like slope and drainage, and visual representation through overlaying the orthomosaic on the DEM. While omitting specific details about the project area and in-depth software tutorials, this report provides a comprehensive overview of the methodology and workflow for utilizing UAV technology and advanced software to create accurate and informative topographical maps.

2 LITERATURE REVIEW

The study of (Ismael & Henari, 2019) showed that the UAV photogrammetry for large scale topographic mapping could replace other methods effectively such as GPS and Total station because the accuracies obtained were within the limits of specifications. In addition to that, the time required are reduced remarkably, more extensive coverage capability, less human interference, different types of output at the same time, and finally, the aerial images are permanent documents that can be referred to at any time in future. The flight mission does not take long time to complete it. The process of establishing the GCP and CP using the GPS technique take some time. The UAV digital images processing took the longest time compared to other stages. However, all the photogrammetric output such as orthophoto, DTM, 3D-model and point cloud were successfully produced (Ahmad et al., 2018b). (Azmi et al., 2014b) found that based on the results and analyses obtained from their study, it can be concluded that the UAV images are suitable replacement for cloud covered area and for updating topographic map. UAVs are becoming increasingly popular as photogrammetric platforms for civilian use due to their relatively low cost and ease of operation. They have the ability to provide accurate data at a higher ground resolution, more economic cost, and more importantly UAV images are cloud free.

GCP) should be added to improve orthophoto accuracy, particularly for vertical precision. The ground control points significantly increase the orthophoto's global precision. The ground control points guarantees that the latitude and longitude of every location in the orthophoto match the real GPS coordinates exactly. The critical point where precision mapping and true accuracy of the global location is required(Azrul et al., 2021). The use of a drone gives us the possibility to map inaccessible, dangerous or difficult areas. Measurements are made remotely, leaving no traces during the measurement in a short time and with high accuracy. The results obtained are orthophotoplanes, digital elevation models or 3D models that can be processed with specialized software, much easier. The emergence of UAV technology combined with GNSS technology is a step forward in obtaining precision measurements with an increased working speed. Another advantage of the new technologies is that they do not require measurements of angles and distances in the field, so many of the inconveniences of total stations will be eliminated, thus leading to a reduction in errors and costs (Simon et al., 2021). A study in Rwanda by (Koeva et al., 2018)demonstrates that UAVs provides promising opportunities to create a high-resolution and highly accurate orthophoto, thus facilitating map creation and updating. The photogrammetric process of obtaining an orthophoto from the individual UAV images is explained and with the support of external high-precision GCPs, the orthophoto created for the case study has planimetric and vertical accuracies less than 8 cm, thus meeting the requirements for 1:1000 scale maps. A number of factors that influence the quality of the orthophoto are highlighted, as well as possible strategies which can be adopted to mitigate these imperfections. The important role of GCPs on increasing the accuracy of the obtained orthophoto is also demonstrated by Koeva. As reported, the geolocation accuracy without external GCPs is relatively low. This can be resolved through the collection of additional high-quality GCPs in the field, which require extra time for collection and insertion in the software. Therefore, UAVs are currently more suitable for map updating projects over a limited study area and incremental map updating.

The combination of UAV and SfM software was able to accurately identify the object position within the scene automatically. With the aid of GCP, the output results can be transformed into local coordinate system though using low-cost and ready-to-fly UAV for mapping. The point cloud then easily generated in to DSM and transferred into ArcGIS and CAD software for topographic plan production. However, a large number of images were produced and need a powerful processor with a large capacity of RAM to speed up the processing (Zainuddin et al., 2015). However, in this particular report we use Pix4D software.

3 SPECIFICATION

Specification of the camera of UAV used during the project is mentioned below. It is a 4th order accuracy project for the topographic map production.

Table 1: Specification Table

Camera Type	DJI FC 2403
No. of Photos	146
Longitudinal Overlap Ratio	70%
Side Overlap Ratio	40%
Altitude	1538 m
Flight Time	15 min 25 sec
Photo Mode	Normal Daylight

4 METHODOLOGY

4.1 Study Area

The study area selected is Dhulikhel (Near Dhulikhel Hospital, LMTC and outside Kathmandu University premises) which lies in Kavre district. Its longitude and latitude extent is 85°32’31.88” E and 27° 37’10.06” N. It is located at the Eastern rim of Kathmandu valley, south of the Himalayas at 1550m above the sea level.

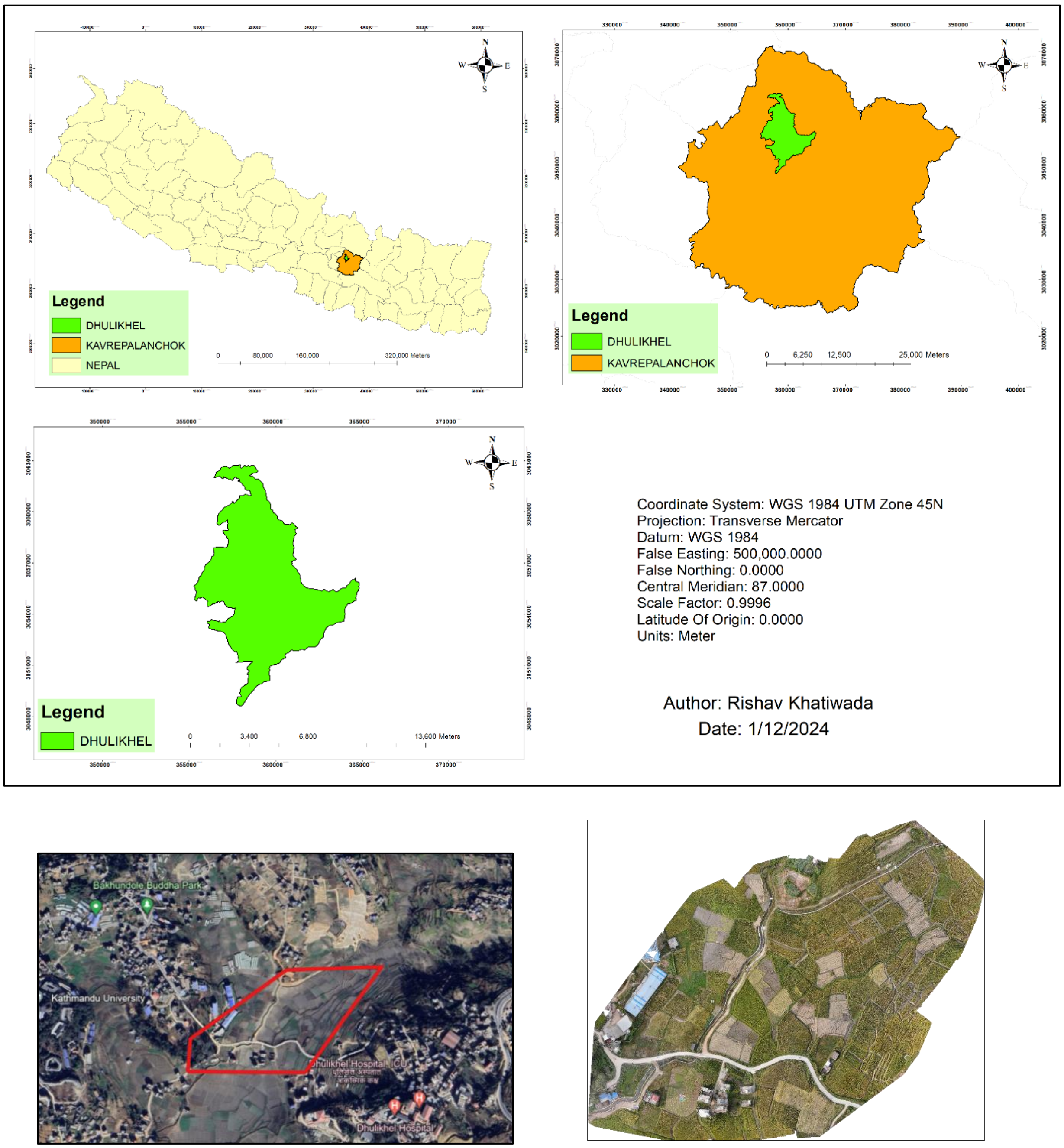

Figure 2: Maps and Images Showing Study Area

4.2 Study Workflow

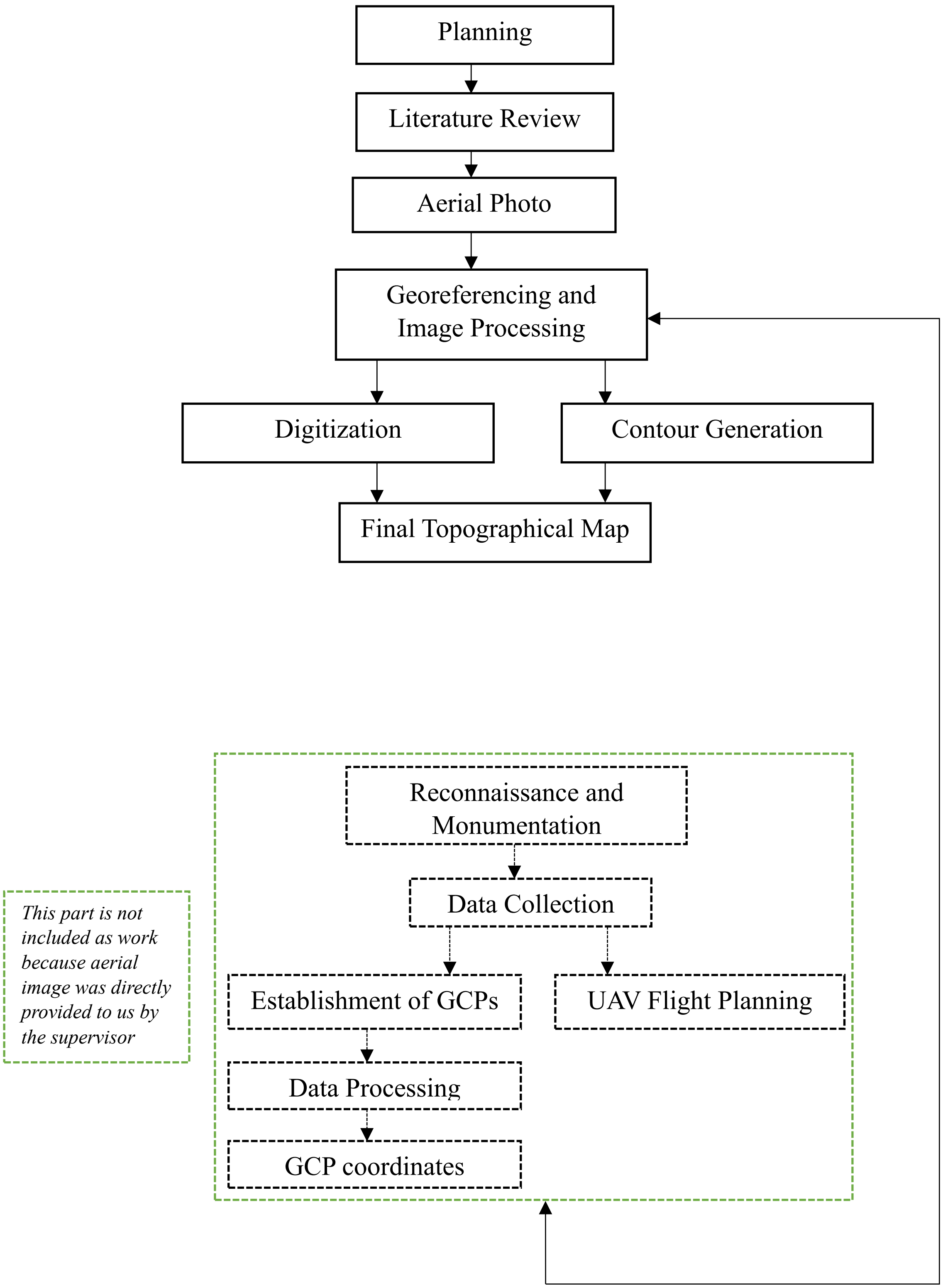

Figure 3: Workflow Diagram

4.3 Digital Image Processing

A digital image is an array, (or matrix) of squares arranged in columns and rows, each square is called a pixel, and each pixel assigned a location x and y, and an intensity number that ranges from 0 (black) to 255 (white). There are two methods of for Image Processing, Analog and Digital Image Processing. An analogue or visual technique of image processing is an interpretation and recognition of images that can be seen on the hard copies such as printouts or photographs.

Digital processing techniques are the manipulation of digital images using computers and software. Pix4Dmapper Pro software was used to process images for a total of 146 photos of the study area acquired by the drone –mavic 2 pro. The software automatically converts these images into accurate georeferenced 3D models and orthophotos, Pix4Dmapper Pro's workflow is carried out in three main steps.

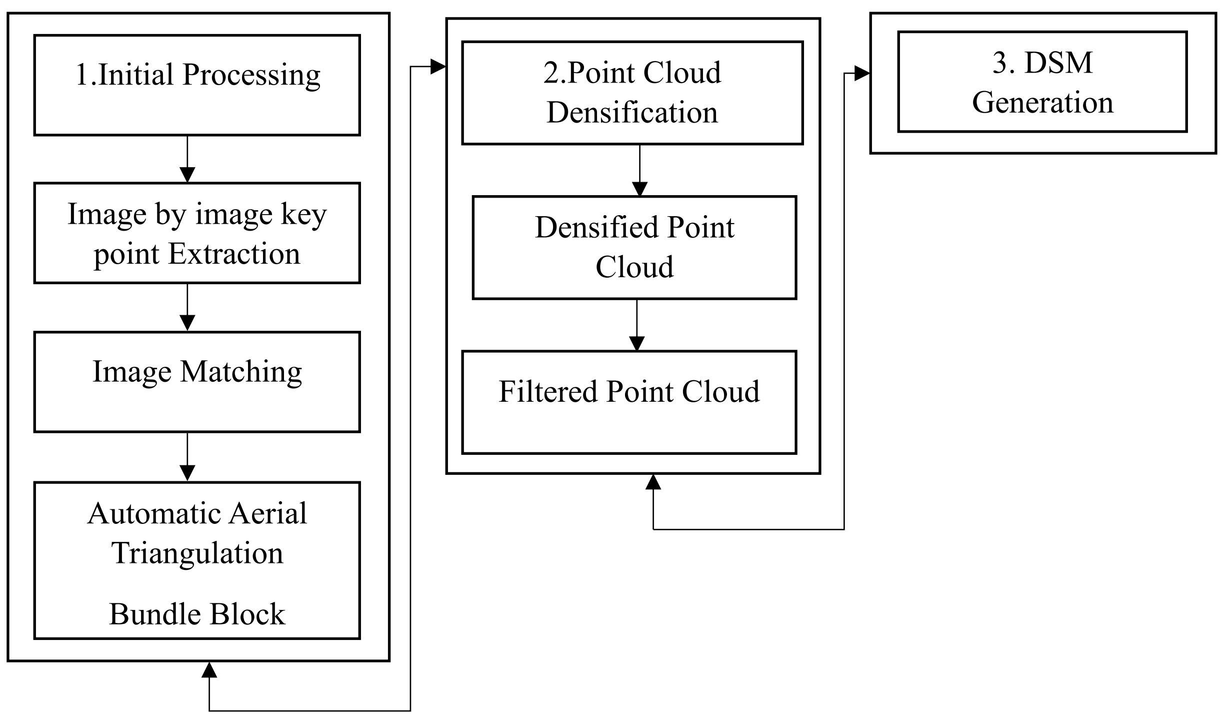

Figure 4: Pix4Dmapper Workflow

Initial processing starts with the Input for Pix4Dmapper software, that is to import raw images and log files recorded during the flight to the computer, log files contain sensor data, camera settings, location of exposure stations and 3D coordinates of control points. Then the software starts to find thousands of common points between images automatically; each of these points is called the key point (points of interest that the software can identify in multiple photos). When two key points on different images are found to be the same, they are matched key points (i.e. image matching). Each group of correctly matched key points will generate one 3D Tie Point. From these initial matches, the software runs automatic aerial triangulation and bundle block adjustment and least squares to reconstruct the exact position and orientation of the camera for every acquired image. The densified point cloud is a set of 3D coordinate points that reconstruct the model; they are computed based on the previous step. The software allows importing point clouds to generate a digital surface model and orthophotos. Subsequently, a various forms of corrected outputs were produced by Pix4Dmapper software based on the generated DSM and orthomosaic such as (DTM) and contour map, a line map was produced by manual digitization using ArcMap Environment (Ismael & Henari, 2019). Figure 4, 5, 6 shows the outputs obtained from UAV Photogrammetry.

Figure 6: Orthomosaic

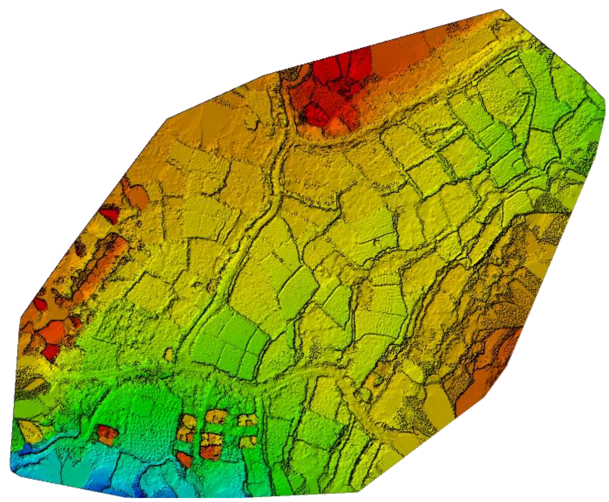

Figure 5: DSM

Figure 7: Contour Lines

5 RESULT

The topographical map obtained shows change in elevation of the selected area from 1472m to 1492m through contour. The majority of the area is used for agriculture but there are also transmission lines, buildings, roads, canals, vegetation, and bare ground. The topographical map obtained using Pix4D and GIS environment is as shown below:

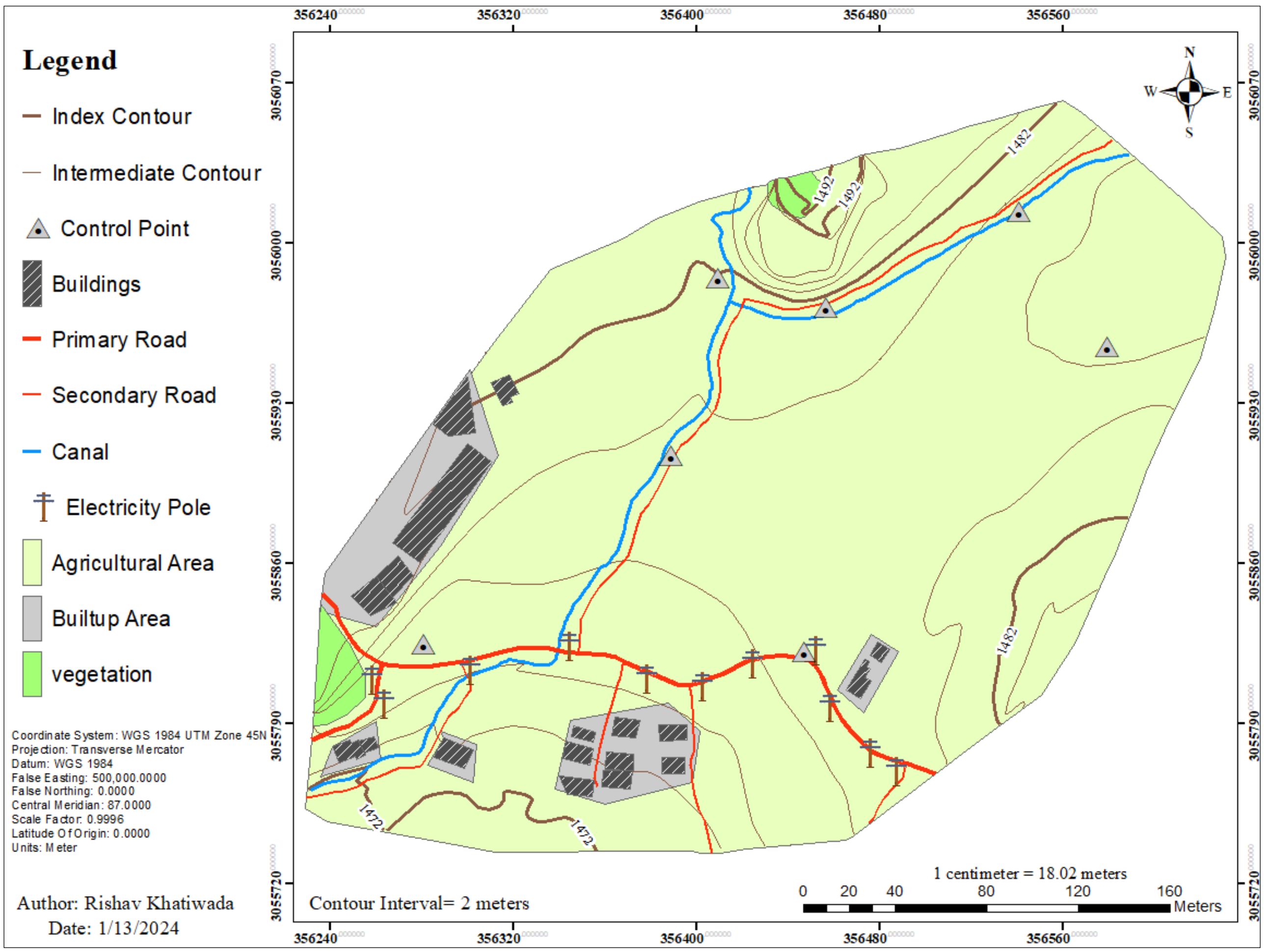

Figure 8: Final Topographic Map

6 CONCLUSION AND RECOMMENDATION

The findings of this study demonstrate how well UAVs, Pix4d, and GIS work together to produce precise and comprehensive topographical maps. In a GIS environment, the process described here results in maps with high resolution, affordable data acquisition, and easily accessible data visualization. The topographical map of the area shows mostly the agricultural land with about 20m variation in terrain.

Investing in suitable UAV technology, learning Pix4d software, and making use of sophisticated GIS tools are among the recommendations. To further optimize this methodology and realize even more potential from this potent combination of technologies, adjustments to the workflow, adherence to best practices, and further investigation into terrain analysis, data integration, and automation are recommended.

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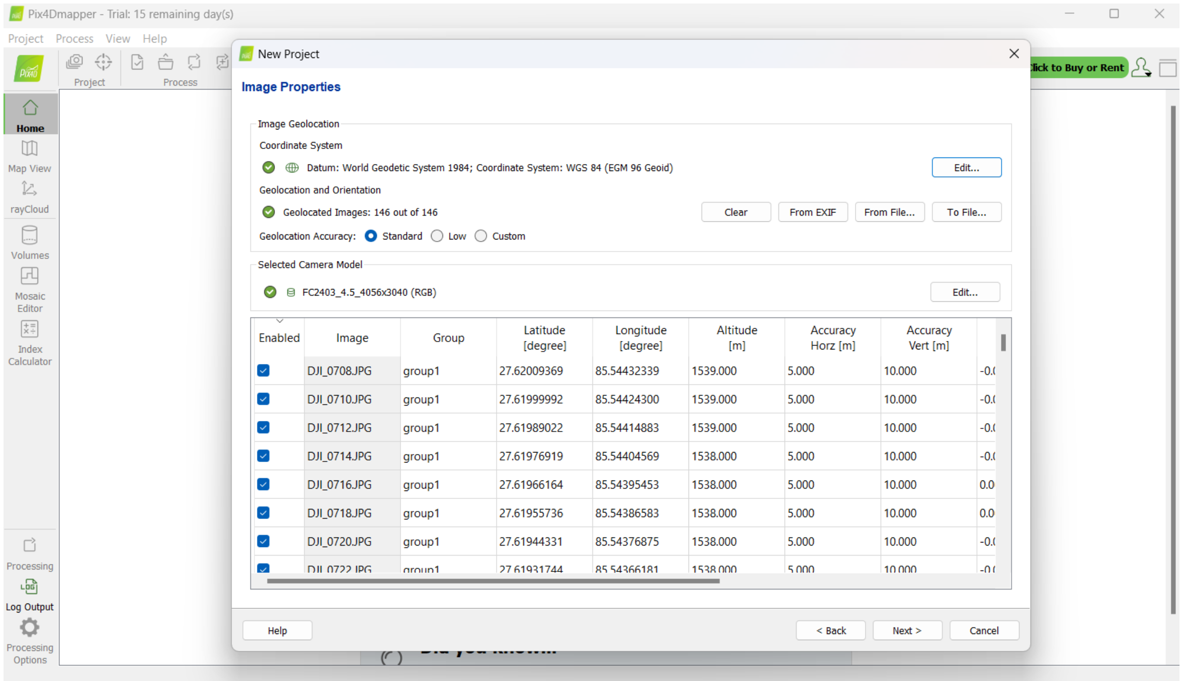
8 ANNEX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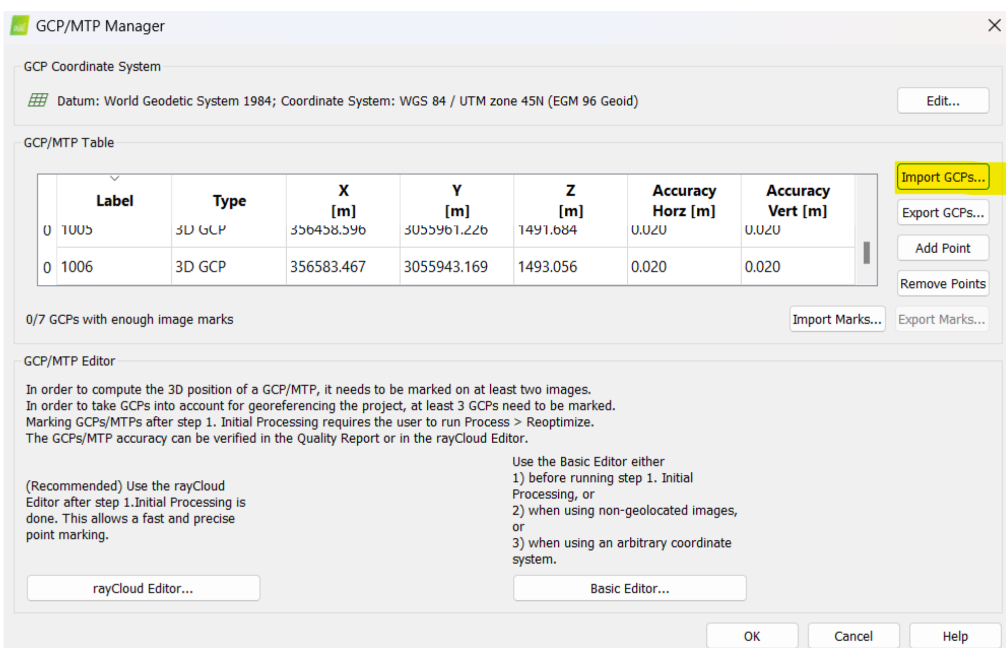
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In order to take GCPs into account for georeferencing the project, at least 3 GCPs need to be marked.
Marking GCPs/MTPs after step 1. Initial Processing requires the user to run Process > Reoptimize.
The GCPs/MTP accuracy can be verified in the Quality Report or in the rayCloud Editor.
(Recommended) Use the rayCloud Editor after step 1.Initial Processing is done. This allows a fast and precise point marking.
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Basic Editor...
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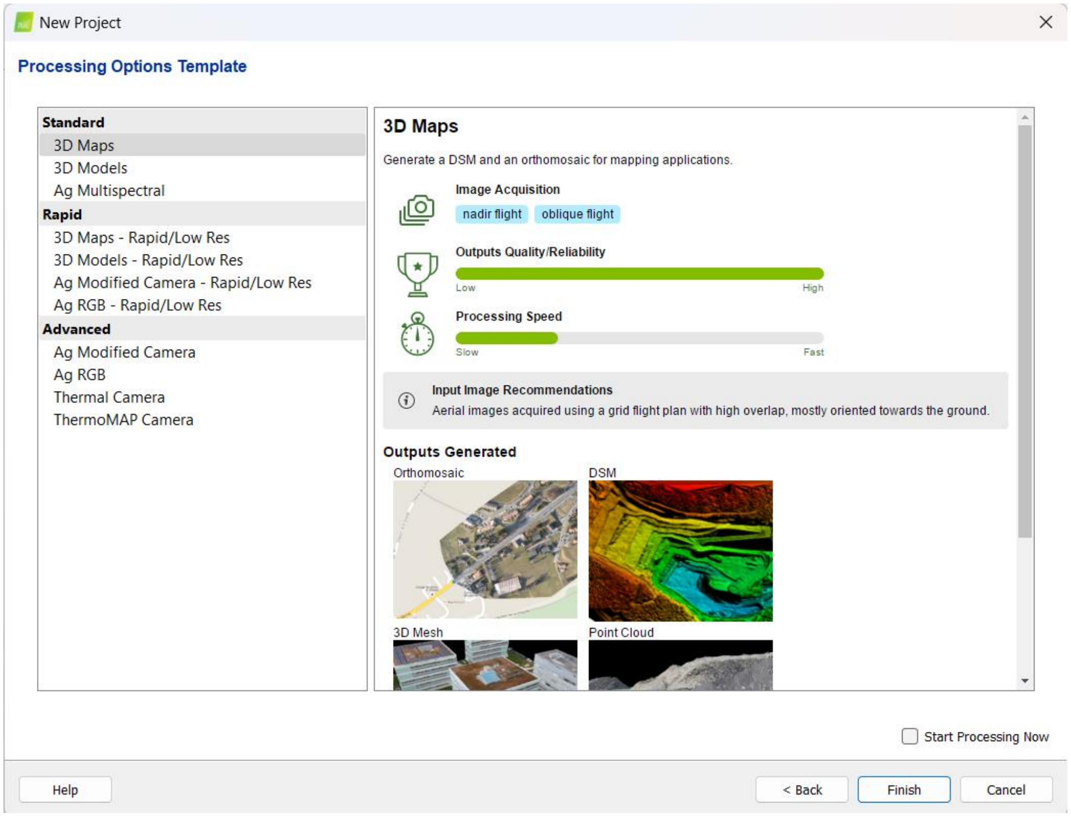
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Rapid
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Generate a DSM and an orthomosaic for mapping applications.
Image Acquisition
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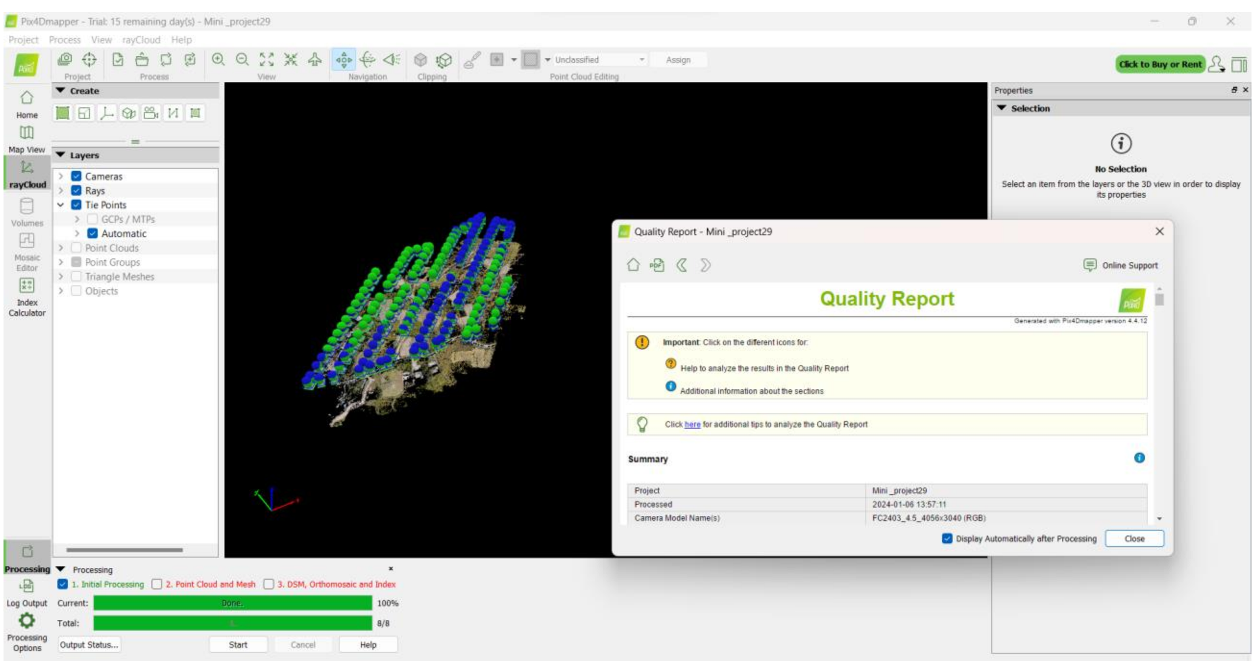
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Quality Report - Mini _project29
Online Support
Quality Report
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Click here for additional tips to analyze the Quality Report
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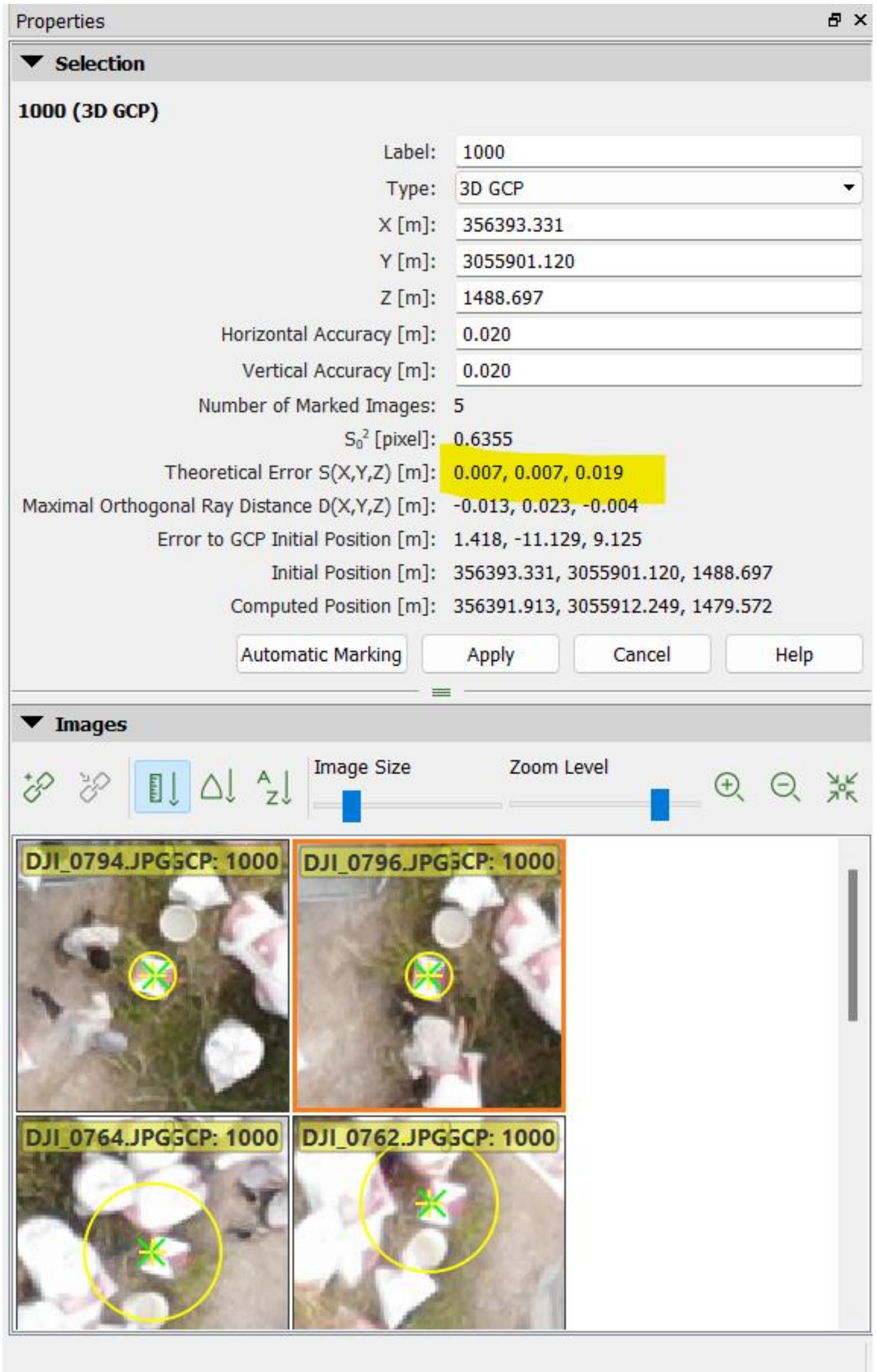
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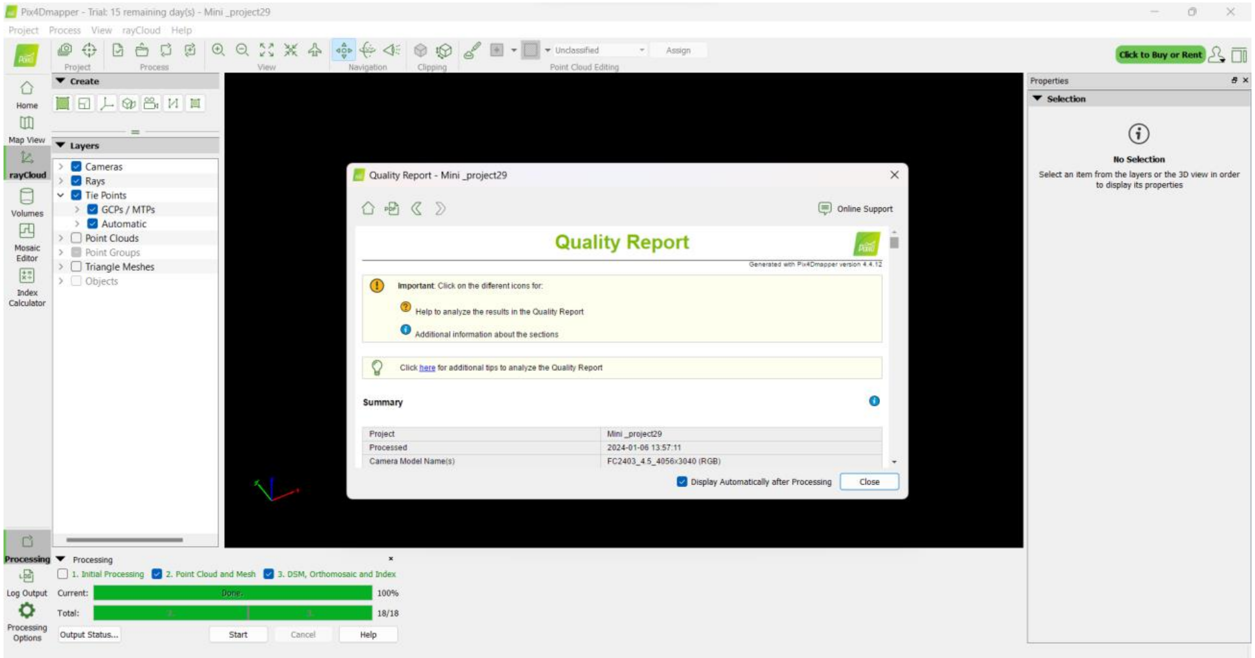
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Automatic
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Triangle Meshes
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Selection
No Selection
Select an item from the layers or the 3D view in order to display its properties
Quality Report - Mini _project29
Online Support
Quality Report
Important: Click on the different icons for:
Help to analyze the results in the Quality Report
Additional information about the sections
Click here for additional tips to analyze the Quality Report
Summary
Project
Mini _project29
Processed
2024-01-06 13:57:11
Camera Model Name(s)
FC2403_4.5_4056x3040 (RGB)
Display Automatically after Processing
Close
Processing
1. Initial Processing
2. Point Cloud and Mesh
3. DSM, Orthomosaic and Index
Current:
Done
100%
Total:
18/18
Output Status...
Start
Cancel
Help
Log Output
Processing Options