KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

Final Report on

Preparation of Topographic Map by Digitization of Drone-processed Data

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ABSTRACT

This report outlines the process and results of creating a topographic map through the digitization of drone-processed data. High-resolution aerial photographs were acquired using advanced drone technology, which followed a pre-determined flight path to ensure comprehensive coverage of the study area. These images were processed using Pix4D to generate a Digital Surface Model (DSM), which was subsequently analyzed in ArcGIS to produce a detailed topographic map. The map accurately depicts elevation contours and significant geographical features. The results highlight the effectiveness of integrating drone technology and GIS for accurate topographic mapping, providing valuable insights for land use planning, infrastructure development, and environmental management. Recommendations for future work include utilizing higher-resolution sensors and incorporating multi-temporal data to enhance accuracy and monitor terrain changes over time.

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LIST OF ABBREVATIONS

DSM	Digital Surface Model
DTM	Digital Terrain Model
GCP	Ground Control Point
GIS	Geographic Information System
UAV	Unmanned Aerial Vehicle

1 INTRODUCTION

1.1 Background

The advent of drone technology has revolutionized the field of geographic data acquisition, providing high-resolution, accurate, and up-to-date spatial information. This report explores the process of preparing a topographic map through the digitization of drone-processed data, showcasing how modern technology can enhance traditional cartographic methods.

Topographic maps are essential tools in various fields, including environmental management, urban planning, engineering, and natural resource exploration. These maps provide detailed information about the terrain, including the location and shape of natural and man-made features. Traditionally, topographic maps were created using ground surveys and photogrammetric techniques, which are time-consuming and labor-intensive. However, the integration of drone technology and advanced software has significantly streamlined this process(Colomina & Molina, 2014).

1.1.1 Unmanned Aerial Vehicle (UAV)

A UAV, short for Unmanned Aerial Vehicle, is an aircraft that operates without a human pilot on board. It can either fly autonomously using pre-programmed flight systems or be controlled remotely. UAV surveying and mapping enable the easy acquisition of reliable and extensive information. UAVs perform aerial surveys over large areas, capturing high-resolution images. These advanced data-collecting machines integrate seamlessly with GIS technology, providing valuable real-time mapping information for geospatial professionals. The unique flight capabilities of UAVs result in sharper imagery and offer distinct advantages(Wolf et al., 2014).

The applications of UAV are as follows:

- **Crop Monitoring**: UAVs equipped with multispectral sensors monitor crop health, detect diseases, and assess growth stages, enabling precision agriculture.
- **Site Surveying**: Conduct aerial surveys to provide accurate topographic maps and 3D models for planning and progress monitoring.
- **Wildlife Conservation**: Monitor wildlife populations, track animal movements, and assess habitats, aiding in conservation efforts.
- **Topographic Mapping**: Create detailed topographic maps by capturing high-resolution aerial images and generating DSMs and orthophotos.
- **Search and Rescue**: Assist in search and rescue operations by covering large areas quickly and providing real-time visuals of difficult terrains.
- **Aerial Filming and Photography**: Capture high-quality aerial footage for films, commercials, and events.
- **Utility Inspection**: Inspect power lines, wind turbines, and pipelines for maintenance and safety checks.
- **Package Delivery**: Deliver goods and medical supplies to remote or inaccessible areas efficiently.
- **Property Marketing**: Provide aerial views of properties to enhance real estate listings and marketing materials.

- **Surveillance**: Conduct aerial surveillance for crowd monitoring, crime scene analysis, and traffic management.

1.1.2 Principle

The working principle of drones is similar to that of airplanes, as both rely on the creation of vertical lift forces due to pressure differences across their rotating blades. In multi-rotor drones, this principle is based on the relative nature of force; when the rotor pushes air downward, the air pushes the rotor upward. This interaction allows the multi-rotor drone to ascend and descend. The speed of the rotor's rotation directly influences the amount of lift generated: faster rotation results in greater lift, and slower rotation results in less lift.

To achieve controllable or autonomous flight, a drone needs to perform several key functions: attitude control, capturing images or measurements, storing and transmitting information, and environmental awareness for collision avoidance. The foundation of automatic control in drones is the closed-loop feedback control system. In this system, changes in control inputs are measured and adjusted continuously until the control output reaches the desired target value(Wolf et al., 2014).

1.1.3 Orthophoto

An orthophotograph is a vertical photograph or mosaic that accurately represents objects in a true planimetric (horizontal) position. This planimetric accuracy enables interpreters to use orthophotos similarly to maps, allowing for direct measurements of geographic locations, distances, angles, and areas. In contrast, unrectified aerial photographs only allow for approximate measurements due to image displacement and scale changes caused by variations in local relief. The orthophoto rectification process eliminates these variations, flattening the local relief to a consistent, uniform scale. When an orthophoto is aligned with controlled map elements, the result is an orthophoto map. This map is highly accurate in terms of equivalence and conformality, representing the same level of detail as a conventional vertical aerial photograph but with the planimetric accuracy of a topographic line map(Ahmad et al., 2018).

1.2 Problem Statement

Accurate topographic maps are crucial for applications such as urban planning, environmental management, and infrastructure development. Traditional methods that rely on ground surveys and photogrammetry are often slow, labor-intensive, and hindered by terrain accessibility and safety issues. Unmanned Aerial Vehicles (UAVs) present a promising alternative with their ability to collect high-resolution data efficiently. However, transforming raw drone data into reliable topographic maps involves navigating complex workflows, ensuring data accuracy and consistency, advanced processing and rectification, effective integration with Geographic Information Systems (GIS), and managing environmental factors that can impact data quality. Overcoming these challenges is essential to fully leverage UAV technology for producing precise and useful topographic maps.

1.3 Objectives

The primary objective of this project is to prepare topographic map by processing images captured from drone.

The secondary objectives of this project are:

i. To be familiar with UAV survey in using drone, image processing using Pix4D and integrating with GIS.
ii. To learn digitizing process in GIS

2 LITERATURE REVIEW

The integration of drone technology and Geographic Information Systems (GIS) has revolutionized the field of topographic mapping, offering unprecedented accuracy and efficiency. Recent advancements in drone technology have facilitated the collection of high-resolution aerial imagery, which is essential for creating detailed topographic maps(Colomina & Molina, 2014). Drones equipped with high-resolution cameras can capture vast areas quickly and accurately, making them an invaluable tool for topographic surveying and mapping(Remondino et al., 2012).

Geographic information traditionally relies on tacheometric and total station techniques for 2D mapping, with aerial photogrammetry advancing to produce detailed 2D maps and 3D models. The demand for accurate 2D maps spans civil engineering, town planning, and other fields, supported by software like Ensomosaic, Pix4D, and Agisoft Photoscan for processing UAV data. This review focuses on using UAVs and photogrammetry to create large-scale 2D maps of Universiti Teknologi Malaysia's campus in Johor Bahru using Agisoft Photoscan and AutoCAD Map, achieving sub-meter accuracy compared to ground surveys. This approach offers rapid, precise mapping solutions crucial for diverse applications.(Ahmad et al., 2018).

One of the primary benefits of using drones for topographic mapping is their ability to provide detailed and accurate Digital Surface Models (DSMs). DSMs generated from drone imagery have been shown to have a high degree of accuracy when compared to traditional surveying methods. For instance, Pix4D, a popular photogrammetry software, processes aerial images to create DSMs and other geospatial data products with high precision (Nex & Remondino, 2014). The ability to generate accurate DSMs is crucial for various applications, including land use planning, infrastructure development, and environmental management (Bühler et al., 2016).

3 METHODOLOGY

3.1 Study Area

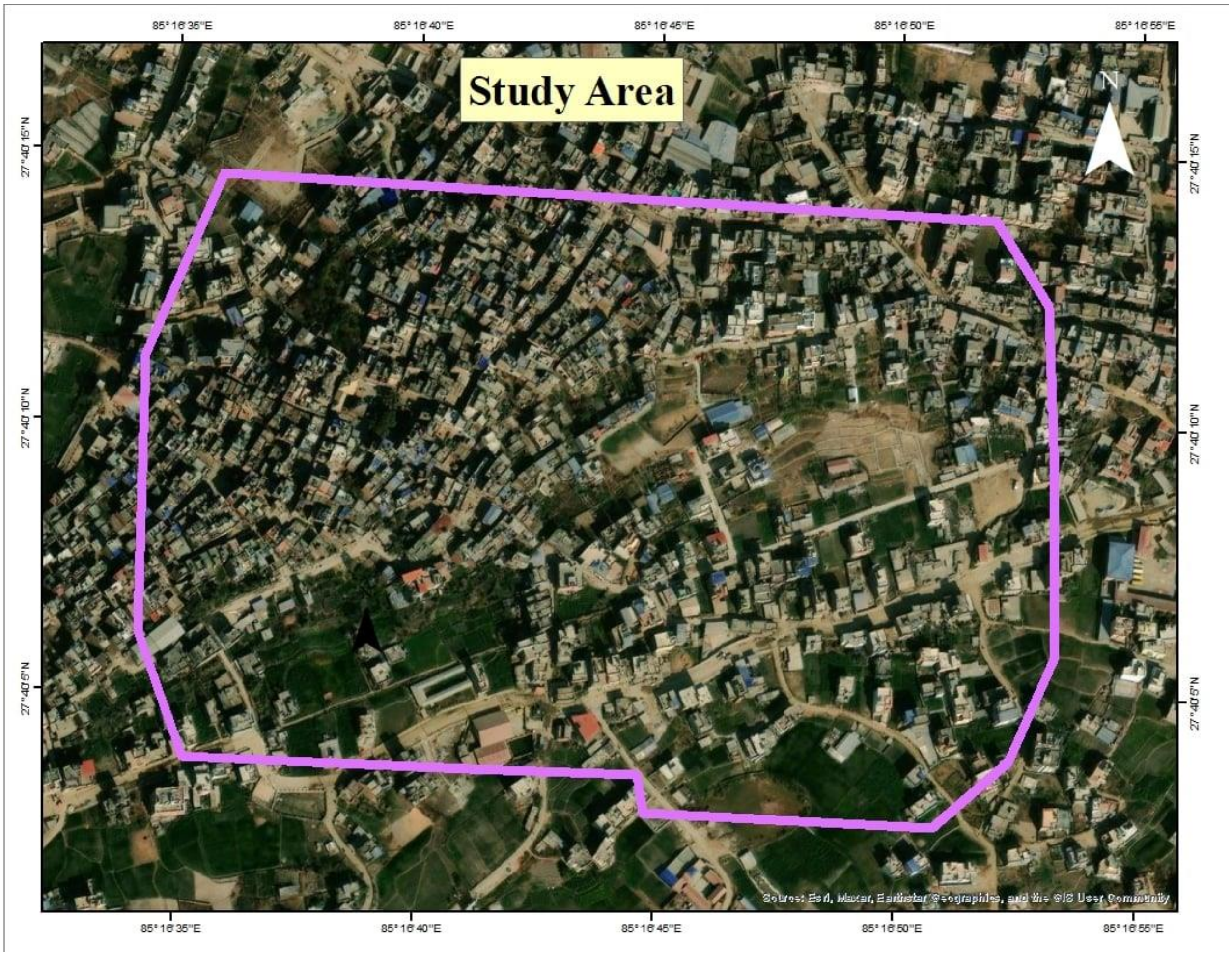

Figure 1: Study area

The study area is situated within coordinates approximately 27°40'3"N to 27°40'14"N and 85°16'34" to 85°16'53" and encompasses a mix of agricultural fields and residential buildings. There are no main highways but number of small roads are present in the area. The elevation rage of this area is also very small as there is no significant elevation changes.

3.2 Study Workflow

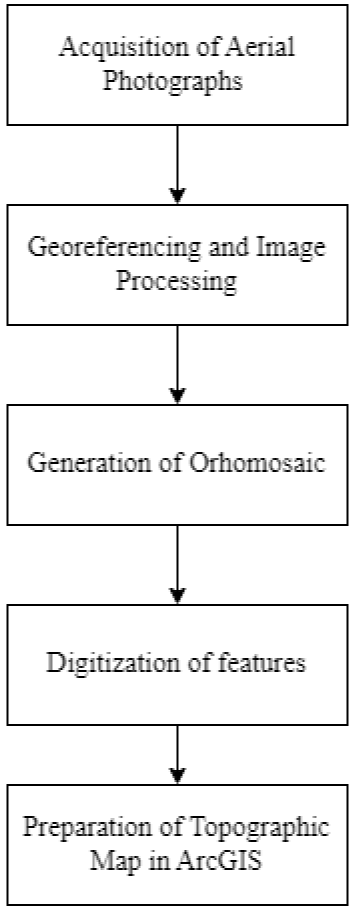

Figure 2: Project Workflow

- **Acquisition of Aerial Photograph**
  Aerial pictures were obtained from a secondary source. These photographs were captured utilizing modern drone technology with high-resolution cameras. To provide thorough coverage, the drones flew over the study area along a predetermined flight route.
- **Geo referencing and Image Processing**
  Pix4Dmapper software was used to process images of the study area acquired by the drone. The software automatically converted these images into accurate georeferenced 3D models and orthophotos.
- **Generation of Orthomosaic**
  The generation of the ortho mosaic involved processing the selected georeferenced images to create a seamless and continuous image of the study area. This began with aligning each image using ground control points (GCPs) and metadata such as GPS coordinates, followed by advanced software algorithms detecting common features in overlapping areas for precise alignment. Geometric distortions were corrected through orthorectification techniques, ensuring a uniform scale across the mosaic. Colour balancing and blending techniques were applied to eliminate visible seams and ensure uniformity in lighting and colour. Rigorous quality control checks were performed, comparing the mosaic with

reference data and correcting any errors or artefacts. The final high-resolution ortho mosaic, saved in a standard geospatial file format with associated metadata, provided an accurate representation of the study area and served as the foundation for further land use analysis.

Figure 3: Orthomosaic

- **Digitization of Features**
  The digitizing process in GIS involves tracing features to convert geographic data into vector data, such as points, lines, or polygons. This process involved capturing features as coordinates in point, line, or polygon format. Building were digitized as polygon, roads as line, and temples as point and so on.

- **Preparation of Topographic map in ArcGIS**
  ArcGIS 10.8 was used to create topographic map of study area. Contour, symbology and other cartographic elements were easily used using ArcGIS software.

3.3 Data Used

105 aerial photographs of study area was used which was provided by course instructor.

3.4 Software Used

Pix4D software was used for image processing and generation orthomosaic. For digitizing and final map preparation ArcGIS version 10.8 was used.

4 RESULTS

Below is the topographic map of the study area, illustrating the terrain features, elevation contours, and other relevant geographical elements. The topographic map of the study area, generated through the digitization of drone-processed data, reveals detailed elevation contours and significant geographical features. The map, produced by processing high-resolution aerial photographs in Pix4D to create a Digital Surface Model (DSM) and further analyzed in ArcGIS, accurately depicts the terrain with contour intervals of 1 meters. Key features such as temples, permanent and temporary buildings, and major roads are clearly identified.

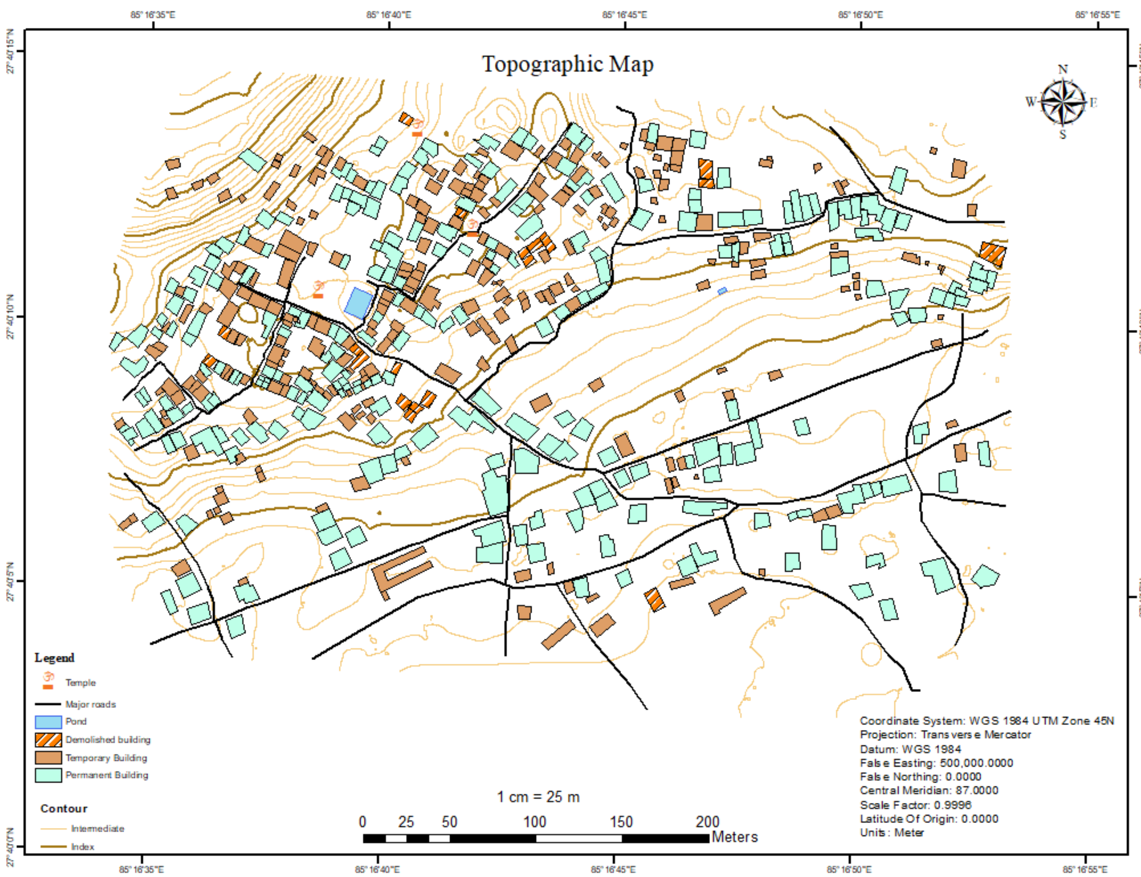

Figure 4: Topographic map

5 CONCLUSION AND RECOMMENDATION

The project successfully demonstrated the preparation of a topographic map through the digitization of drone-processed data. By employing advanced photogrammetry techniques in Pix4D and further analysis in ArcGIS, we were able to create a highly detailed and accurate topographic map of the study area. The resulting map provides a clear representation of the terrain, with precise elevation contours and identifiable geographical features, making it an invaluable tool for various applications such as land use planning, infrastructure development, and environmental management.

For future projects, it is recommended to incorporate higher-resolution drones and sensors to capture even more detailed aerial photographs, enhancing the accuracy and resolution of the topographic maps. Additionally, expanding the scope to include multi-temporal data could provide insights into terrain changes over time, benefiting environmental monitoring and disaster management. Further research could explore the integration of machine learning algorithms for automated feature extraction and classification, streamlining the map creation process. Addressing limitations such as weather conditions during data capture can also improve the consistency and reliability of the results. Overall, continued advancements in drone technology and GIS will further enhance the precision and applicability of topographic maps in various fields.

6 REFERENCES

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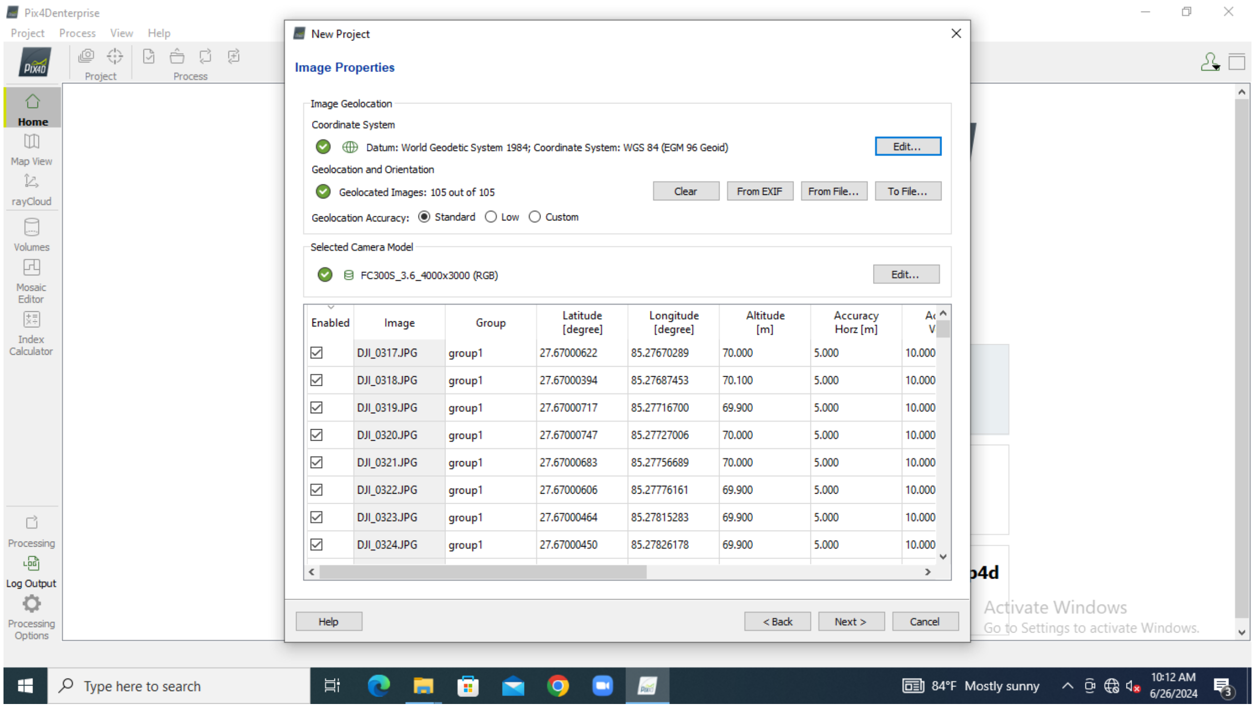
Wolf, P. R., Dewitt, B. A., Wilkinson, B. E., & York Chicago San Francisco Athens London Madrid, N. (2014). *Elements of Photogrammetry with Applications in GIS Fourth Edition*. www.mhprofessional.com.

7 ANNEXES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Next >
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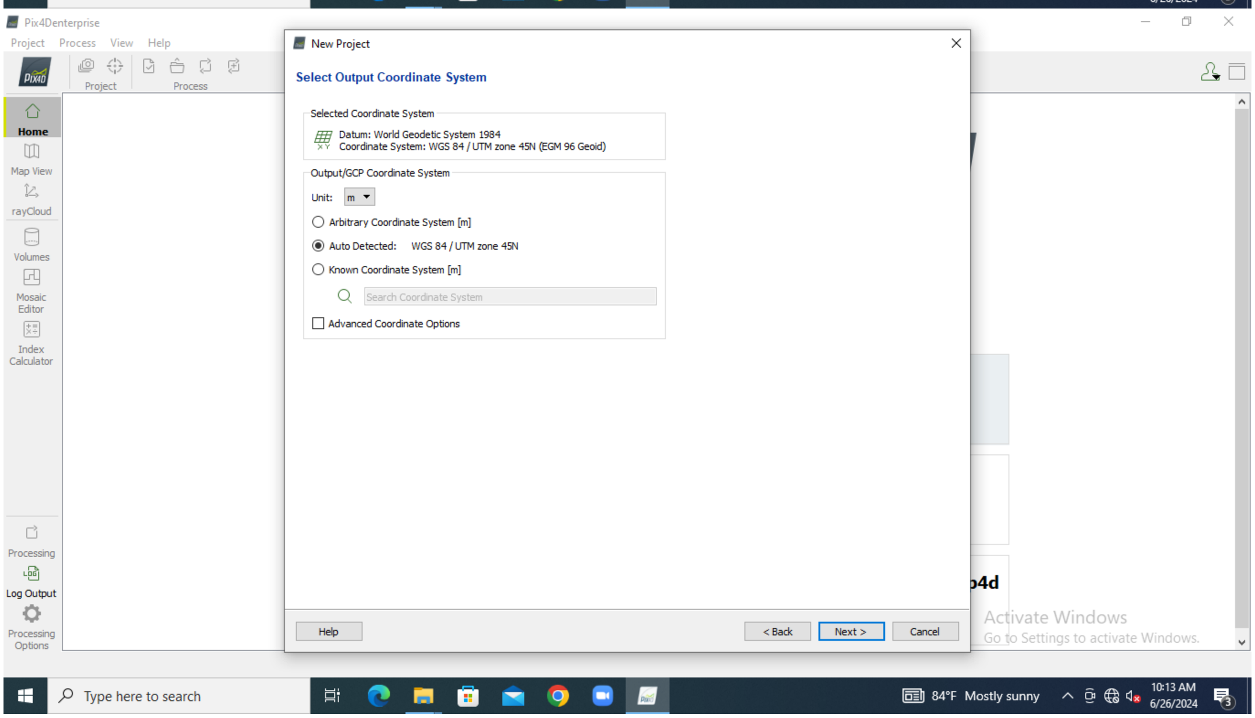
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Output/GCP Coordinate System
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Next >
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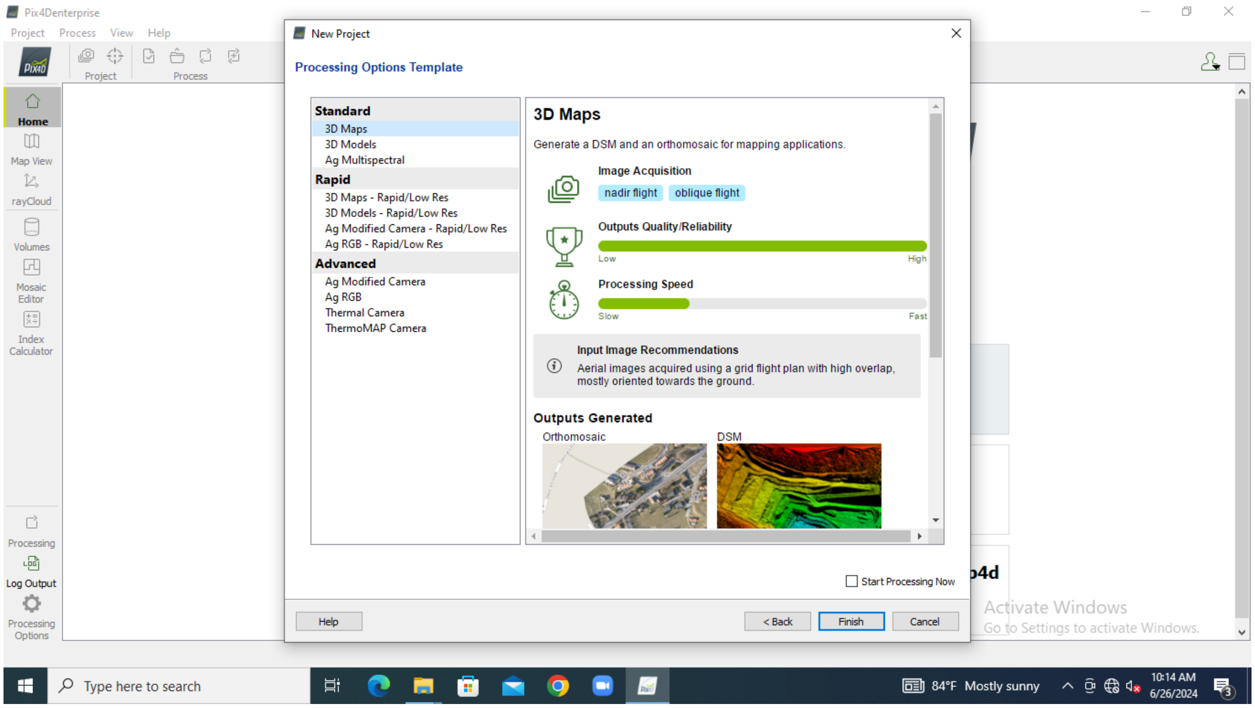
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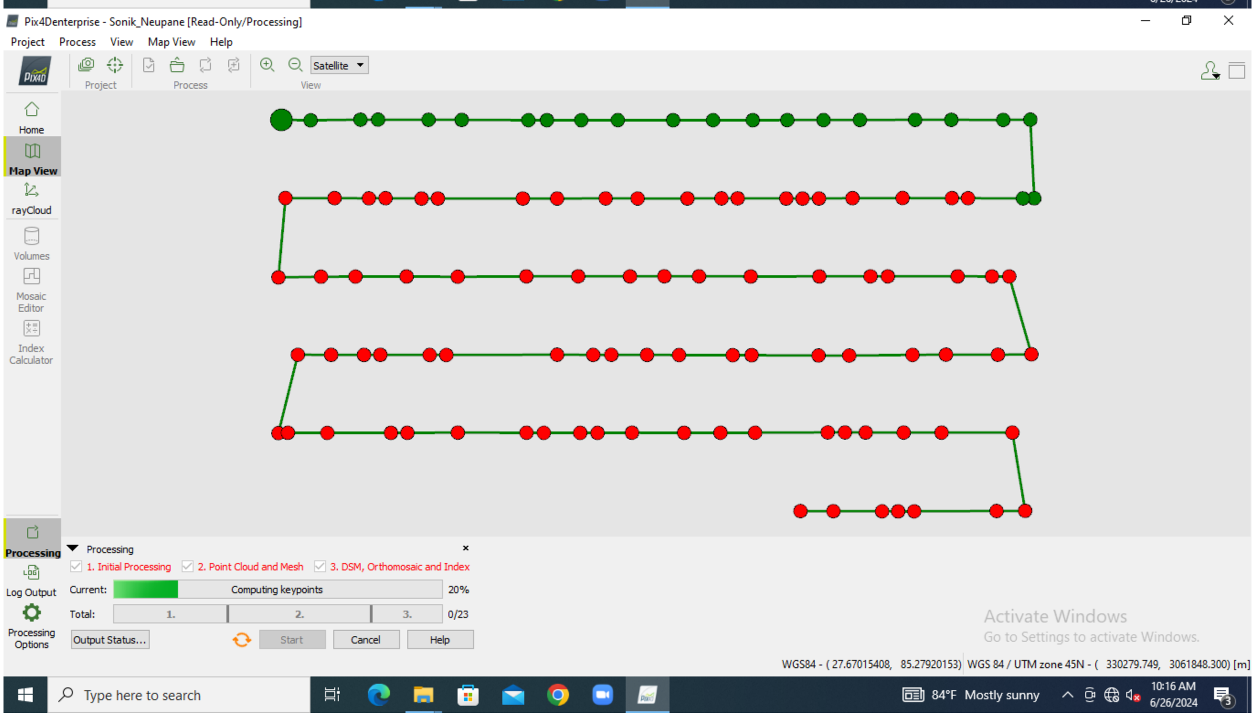
Standard
3D Maps
3D Models
Ag Multispectral
Rapid
3D Maps - Rapid/Low Res
3D Models - Rapid/Low Res
Ag Modified Camera - Rapid/Low Res
Ag RGB - Rapid/Low Res
Advanced
Ag Modified Camera
Ag RGB
Thermal Camera
ThermoMAP Camera
3D Maps
Generate a DSM and an orthomosaic for mapping applications.
Image Acquisition
nadir flight
oblique flight
Outputs Quality/Reliability
Processing Speed
Input Image Recommendations
Aerial images acquired using a grid flight plan with high overlap, mostly oriented towards the ground.
Outputs Generated
Orthomosaic
DSM
Start Processing Now
Help
< Back
Finish
Cancel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Processing
1. Initial Processing
2. Point Cloud and Mesh
3. DSM, Orthomosaic and Index
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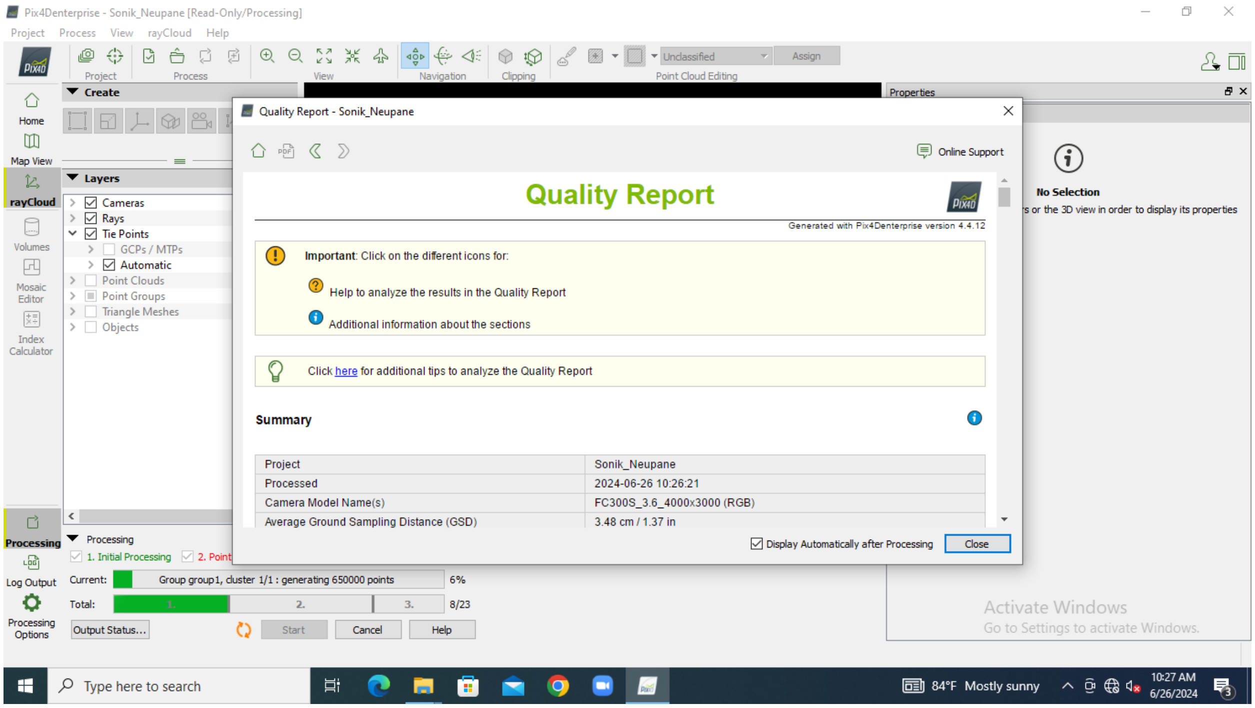
Output Status...
Start
Cancel
Help


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 Sonik_Neupane
Processed 2024-06-26 10:26:21
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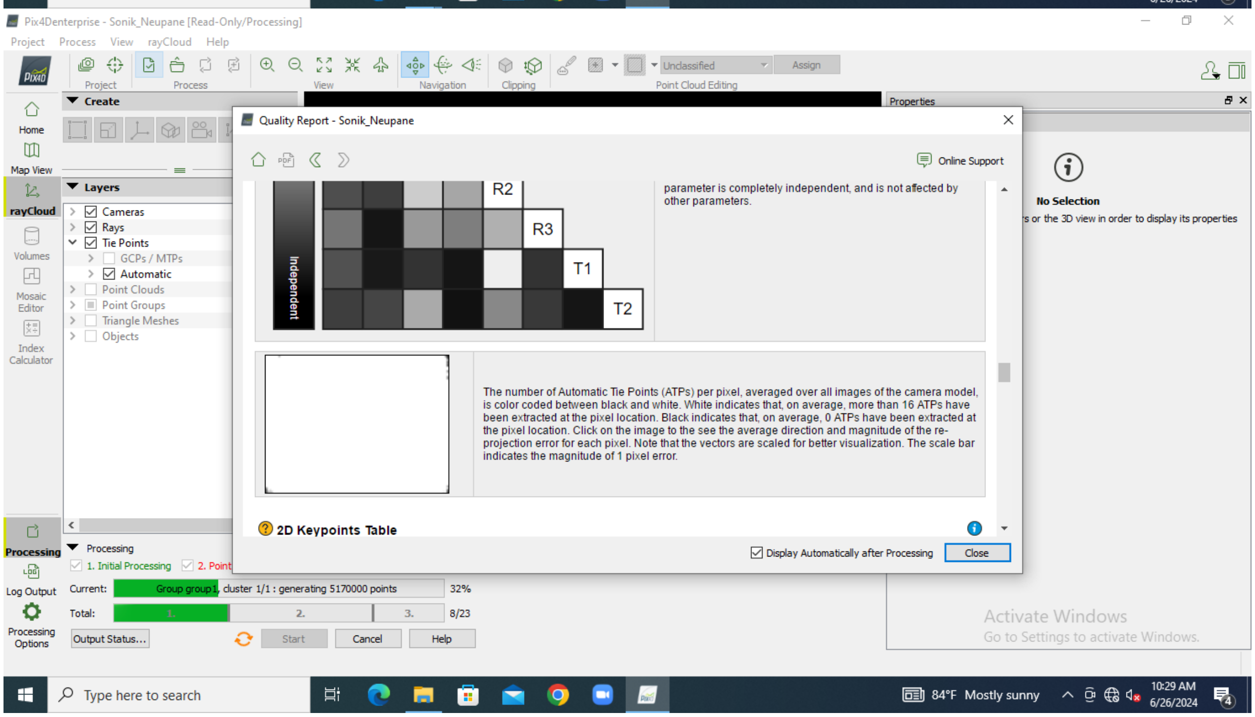
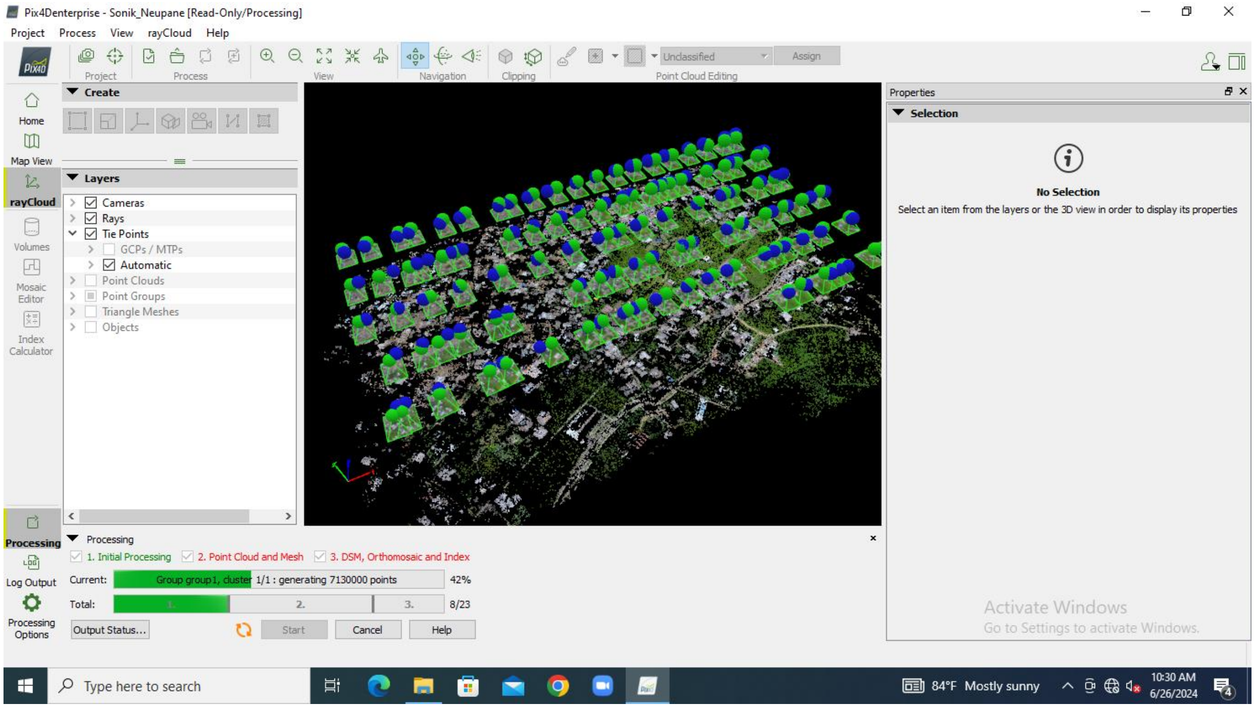

The number of Automatic Tie Points (ATPs) per pixel, averaged over all images of the camera model, is color coded between black and white. White indicates that, on average, more than 16 ATPs have been extracted at the pixel location. Black indicates that, on average, 0 ATPs have been extracted at the pixel location. Click on the image to the see the average direction and magnitude of the re-projection error for each pixel. Note that the vectors are scaled for better visualization. The scale bar indicates the magnitude of 1 pixel error.
2D Keypoints Table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Project Process View rayCloud Help
Properties
Selection
No Selection
Select an item from the layers or the 3D view in order to display its properties
Layers
Cameras
Rays
Tie Points
GCPs / MTPs
Automatic
Point Clouds
Point Groups
Triangle Meshes
Objects
Processing
1. Initial Processing
2. Point Cloud and Mesh
3. DSM, Orthomosaic and Index
Current: Group group1, cluster 1/1 : generating 7130000 points 42%
Total: 8/23
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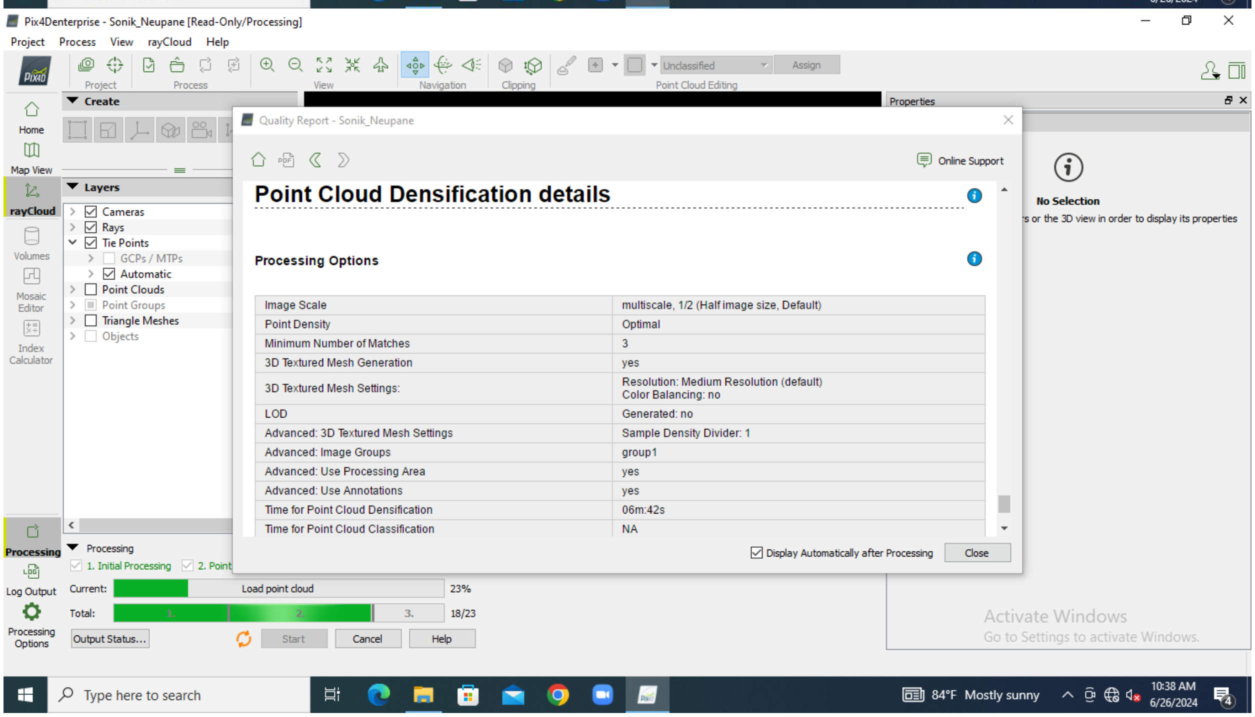
Cancel
Help
Type here to search
84°F Mostly sunny
10:30 AM
6/26/2024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Quality Report - Sonik_Neupane
Online Support
Point Cloud Densification details
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Minimum Number of Matches 3
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LOD Generated: no
Advanced: 3D Textured Mesh Settings Sample Density Divider: 1
Advanced: Image Groups group1
Advanced: Use Processing Area yes
Advanced: Use Annotations yes
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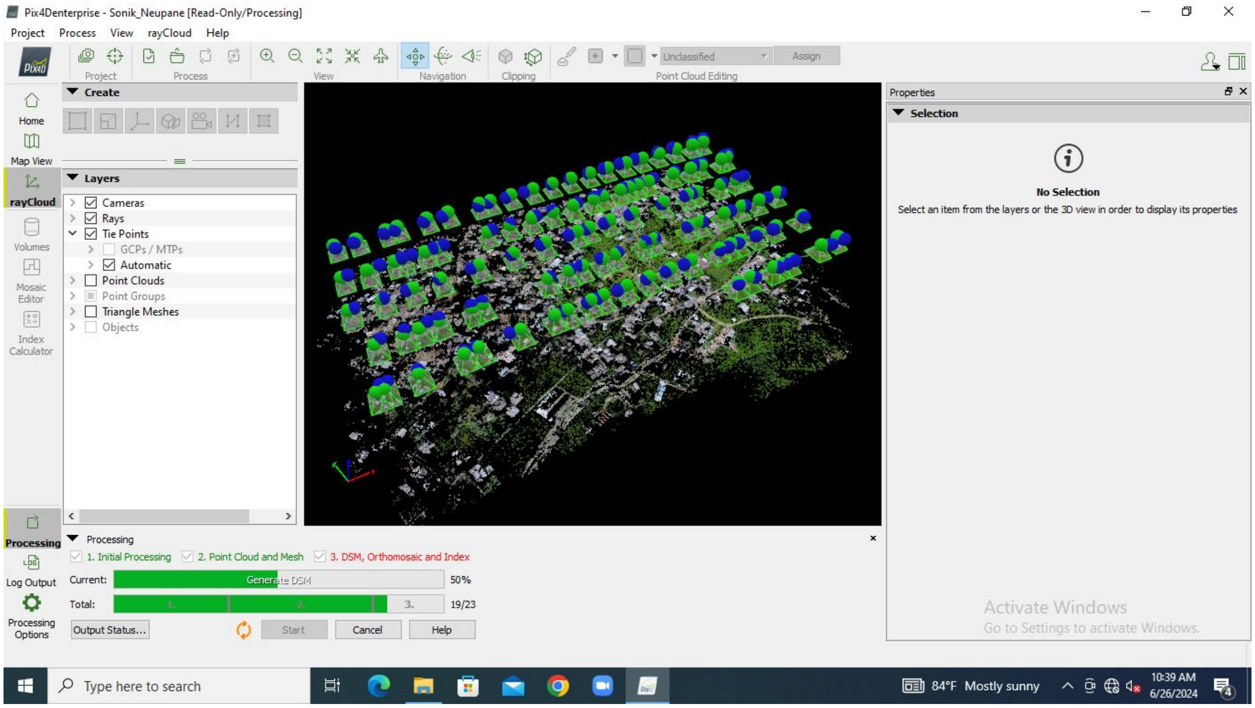
6/26/2024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3. DSM, Orthomosaic and Index
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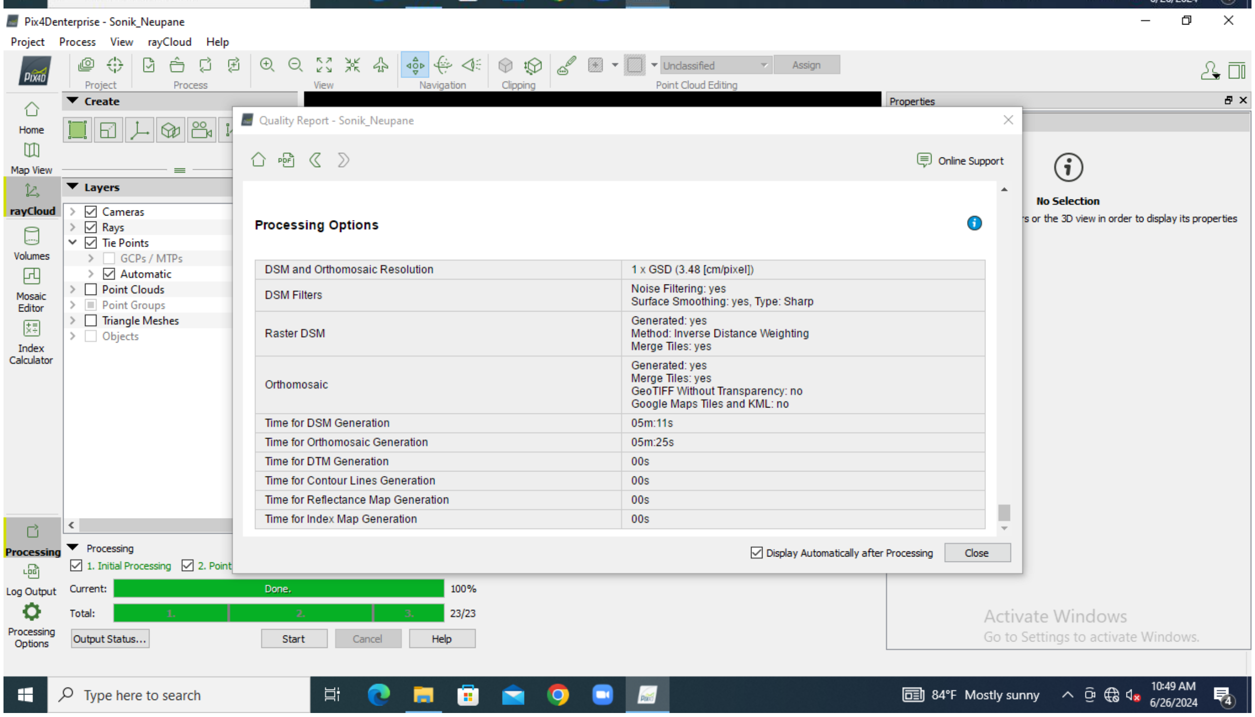
Help


Pix4Denterprise - Sonik_Neupane
Quality Report - Sonik_Neupane
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DSM and Orthomosaic Resolution
1 x GSD (3.48 [cm/pixel])
DSM Filters
Noise Filtering: yes
Surface Smoothing: yes, Type: Sharp
Raster DSM
Generated: yes
Method: Inverse Distance Weighting
Merge Tiles: yes
Orthomosaic
Generated: yes
Merge Tiles: yes
GeoTIFF Without Transparency: no
Google Maps Tiles and KML: no
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05m:11s
Time for Orthomosaic Generation
05m:25s
Time for DTM Generation
00s
Time for Contour Lines Generation
00s
Time for Reflectance Map Generation
00s
Time for Index Map Generation
00s
Display Automatically after Processing
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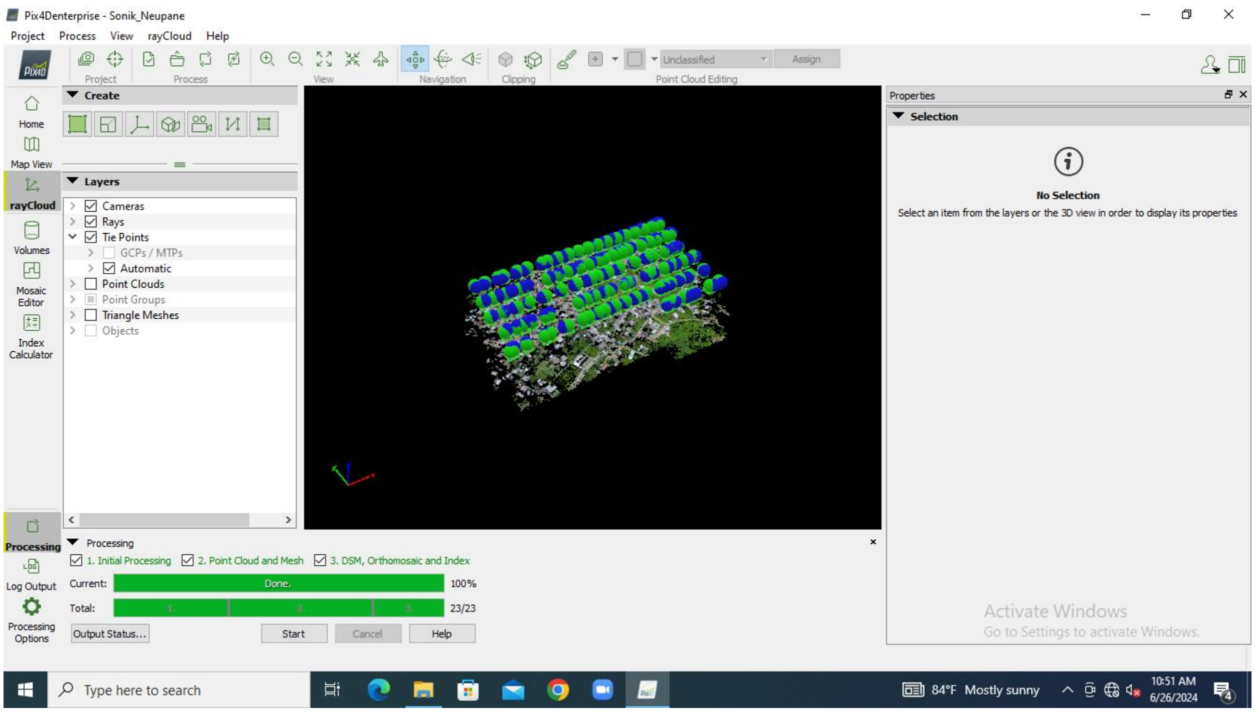
Done.
100%
Total:
23/23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Unclassified
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Create
Home
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Rays
Tie Points
GCPs / MTPs
Automatic
Point Clouds
Point Groups
Triangle Meshes
Objects
Volumes
Mosaic Editor
Index Calculator
Properties
Selection
No Selection
Select an item from the layers or the 3D view in order to display its properties
Processing
1. Initial Processing
2. Point Cloud and Mesh
3. DSM, Orthomosaic and Index
Log Output
Current:
Done.
100%
Total:
23/23
Processing Options
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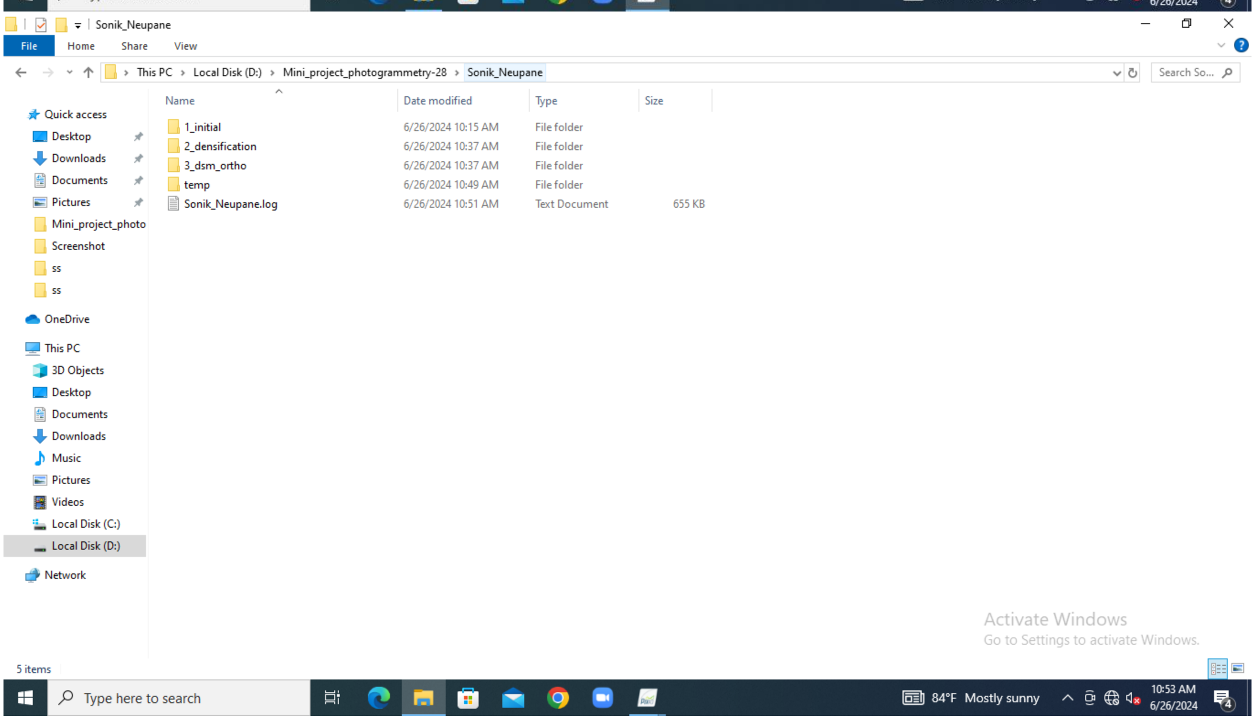
10:51 AM
6/26/2024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Home
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View
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3D Objects
Desktop
Documents
Downloads
Music
Pictures
Videos
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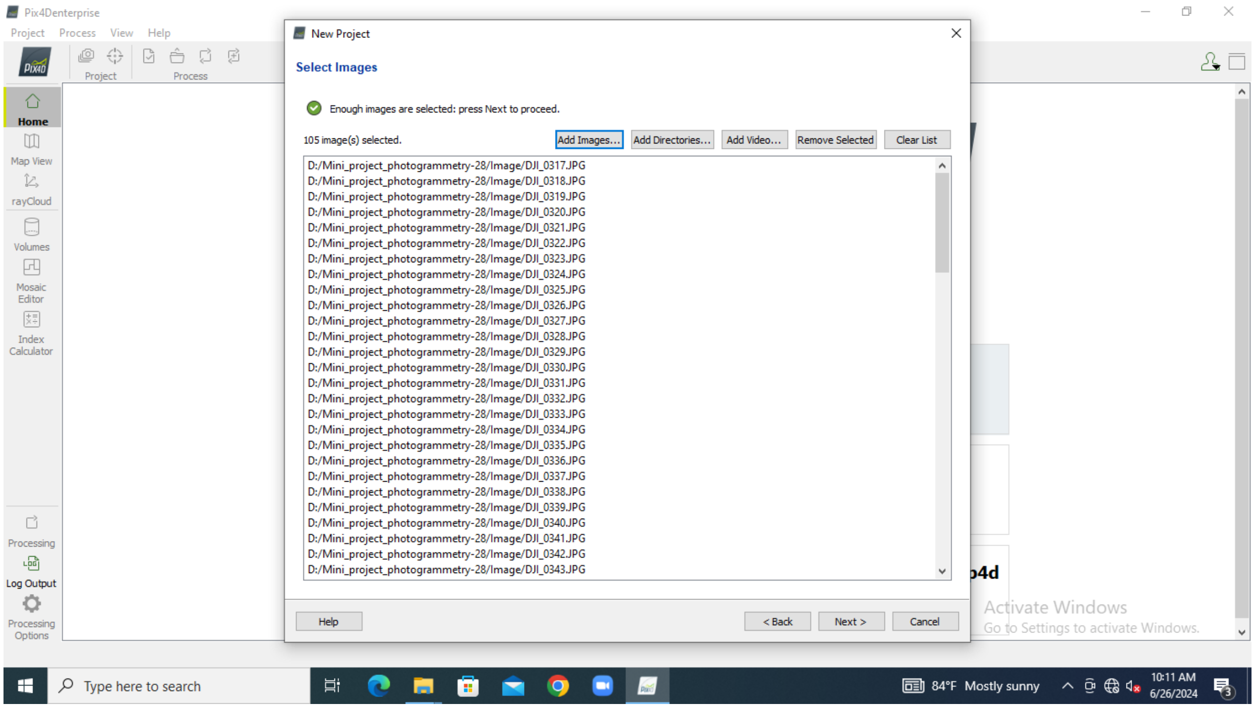
6/26/2024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105 image(s) selected.
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Add Directories...
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Remove Selected
Clear List
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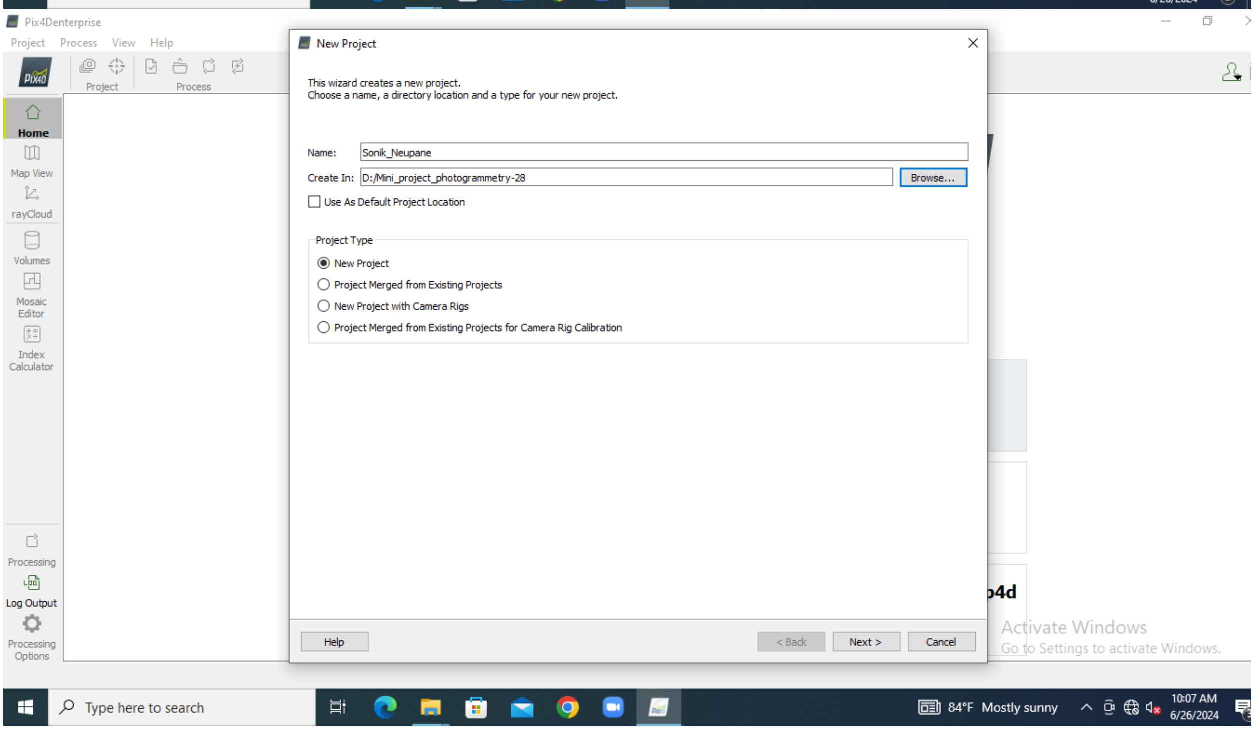
New Project
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Choose a name, a directory location and a type for your new project.
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Browse...
Use As Default Project Location
Project Type
New Project
Project Merged from Existing Projects
New Project with Camera Rigs
Project Merged from Existing Projects for Camera Rig Calibration
Help
< Back
Next >
Cancel