GPS-based 2D Map Creation using Drones Swarm

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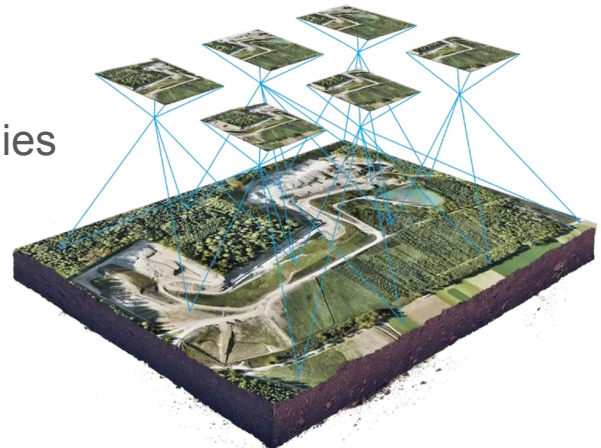
Center of Advanced Software Technologies



Aim of the project

The project aims to optimize area coverage using drones with cameras, followed by creating detailed 2D maps. This involves dividing the area among drones, using custom algorithms to determine optimal paths. Drones capture imagery and GPS data for accurate mapping. Integrated data generates comprehensive maps for monitoring and decision-making.

What we have

1. GPS coordinates of the polygon defining the boundary of the area.
2. GPS coordinates of obstacles inside the polygon.
3. Number of drones.
4. Start and finish points for each drone.
5. Obtaining drone photos for cartography afterward.

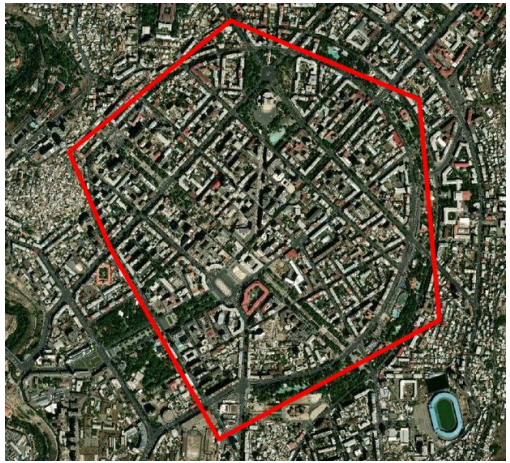
What we need to do

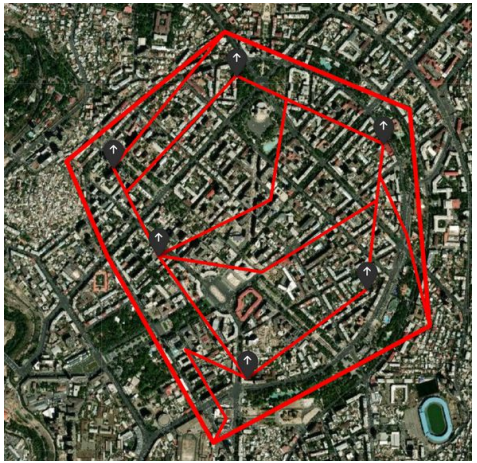
1. Achieve optimal coverage of a given area.
2. Divide the area among the drones to ensure efficient coverage.
3. Implement custom analysis algorithms to determine optimal paths for each drone within their designated zones of responsibility.
4. Supplement visual data with GPS data for accurate georeferencing.
5. Process and integrate visual and GPS data.
6. Generate comprehensive 2D maps of the territory.

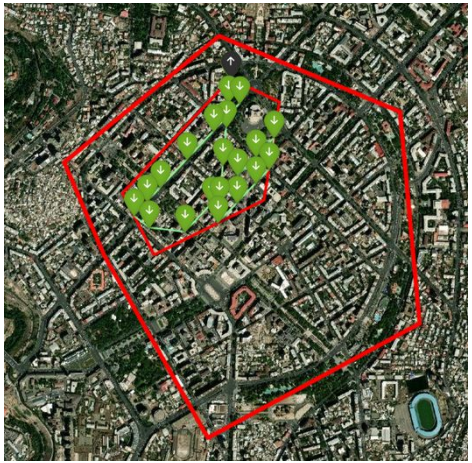
Methodology: Drone Swarm

Solution consists of two parts:

1. Dividing the area into parts.
2. Finding the optimal path for each divided area.

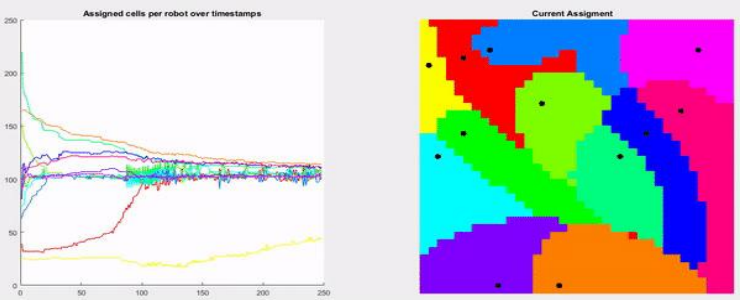






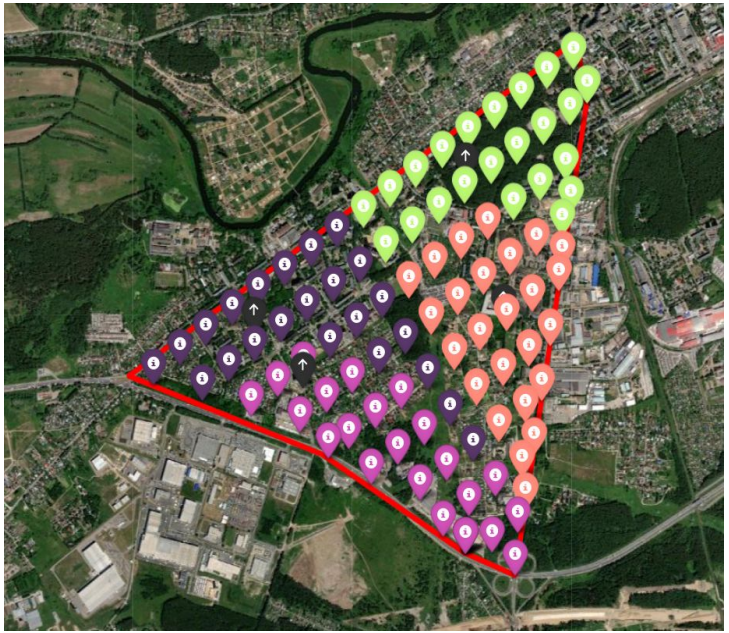
Dividing the area

DARP (Divide Areas based on Robots' Initial Positions)



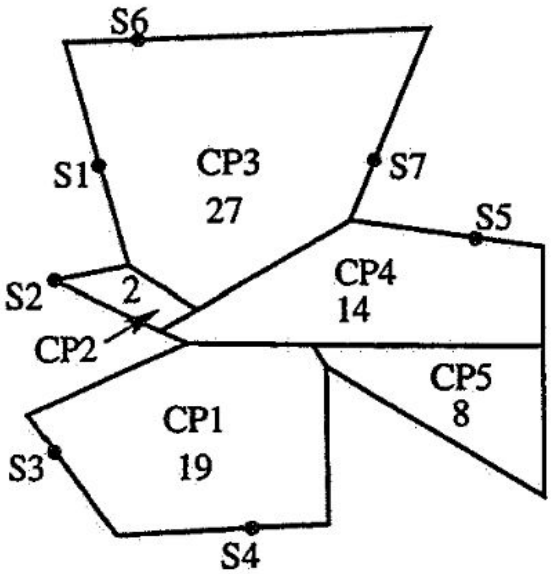
Definition 3 A selection $\{L_1, L_2, \ldots, L_{n_r}\}$ composes an optimal solution for the mCPP, iff

1. $L_i \cap L_j = \emptyset, \forall i, j \in 1, \ldots, n_r\ , i \neq j$
2. $L_1 \cup L_2 \cup \cdots \cup L_{n_r} = \mathcal{L}$
3. $|L_1| \approx |L_2| \cdots \approx |L_{n_r}|$
4. L_i is connected $\forall i \in 1, \ldots, n_r$
5. $\chi_i(t_0) \in L_i$



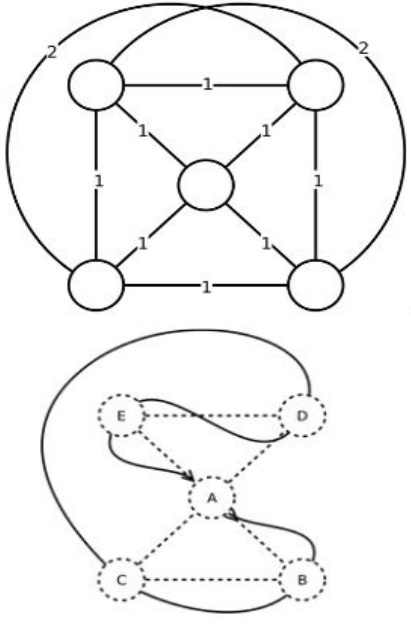
Dividing the area

PODE (Polygon Area Decomposition for Multiple-Robot Workspace Division)



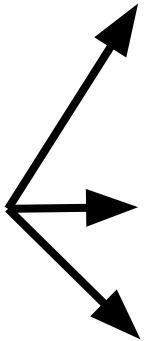
Finding the optimal path for each divided area

TSP (The Traveling Salesman Problem) - Christofides algorithm



Finding the optimal path for each divided area

Back-and-forth methods



Li (Coverage path planning for UAVs based on enhanced exact cellular decomposition method)

Torres (Coverage path planning with unmanned)

RCPP (Rotating Calipers Path Planning)

Finding the optimal path for each divided area

- Li (Coverage path planning for UAVs based on enhanced exact cellular decomposition method)
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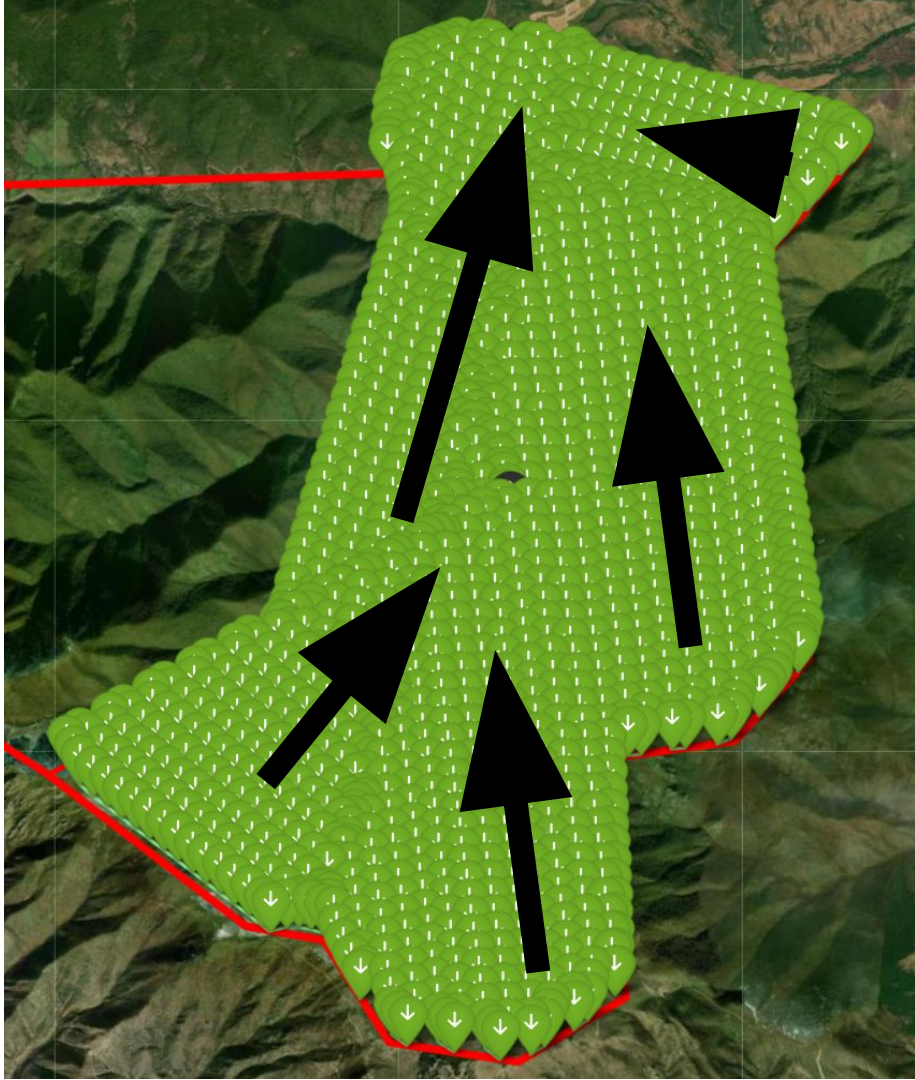
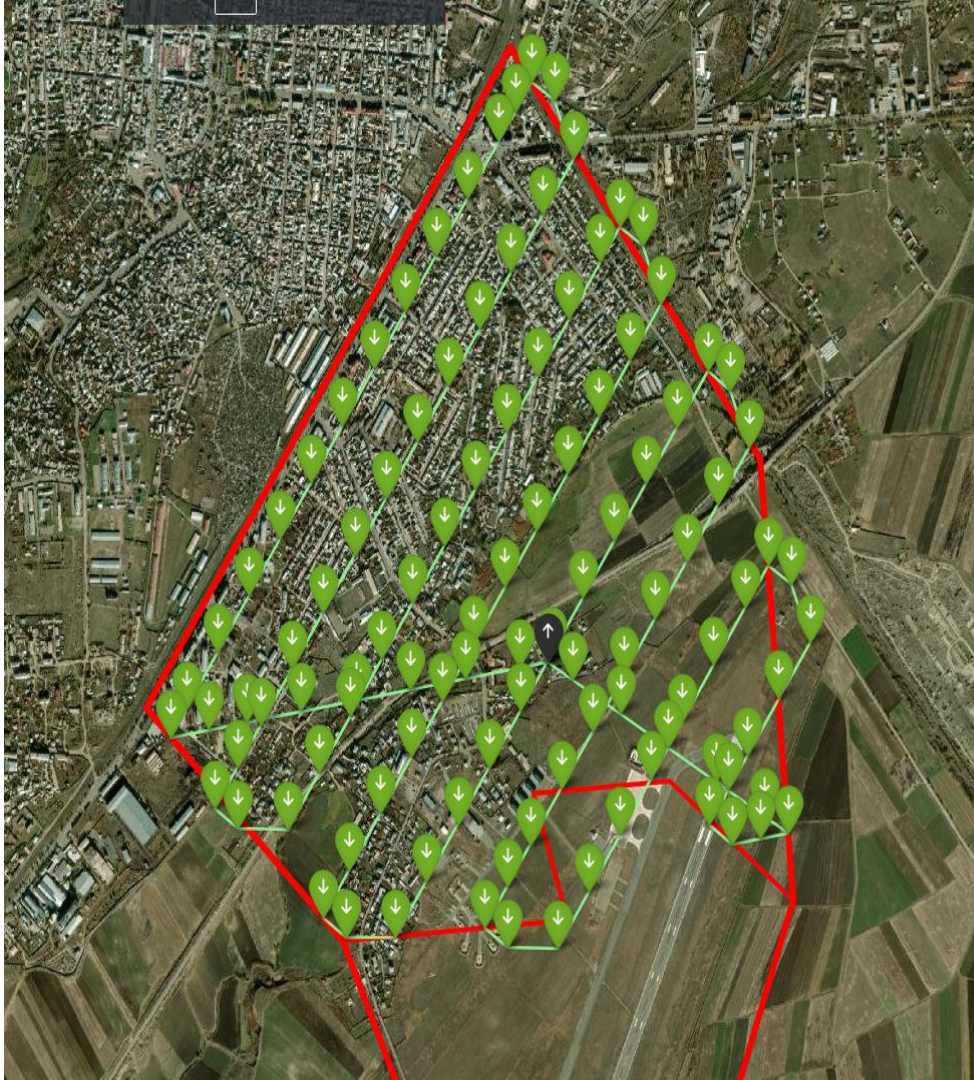


Finding the optimal path for each divided area

- RCPP (Rotating Calipers Path Planning)



Metrics for evaluation

$$\text{COST} = \frac{\sum_i d\left(P_i, P_{i+1}\right)}{V} + \frac{\sum_i \angle\left(\left(\overrightarrow{P_{i-1}, P_i}\right), \left(\overrightarrow{P_i, P_{i+1}}\right)\right)}{\omega}$$

- Evaluation of methods for dividing territories
- Evaluation of methods for optimal coverage of the obtained parts

Methodology: 2D Maps creation

There are applications such as:

- Pix4D,
- DroneDeploy,
- ArcGIS

Which provide a wide range of features—from planning drone routes to creating 2D maps based on aerial imagery. However, long-term usage requires financial investment.

Geographic Information System (GIS)

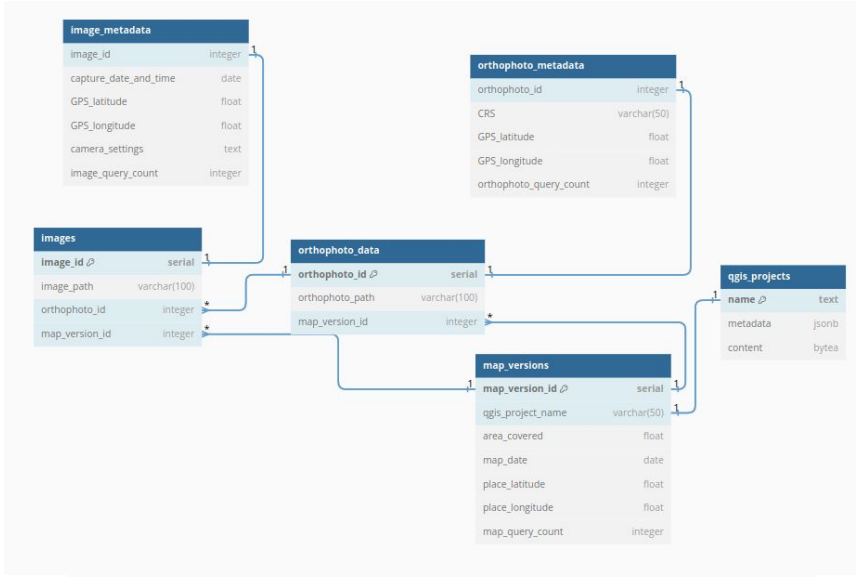
QGIS (Quantum GIS) is a free and open-source geographic information system (GIS) software designed for the analysis, editing, visualization, and processing of spatial data.

Advantages:

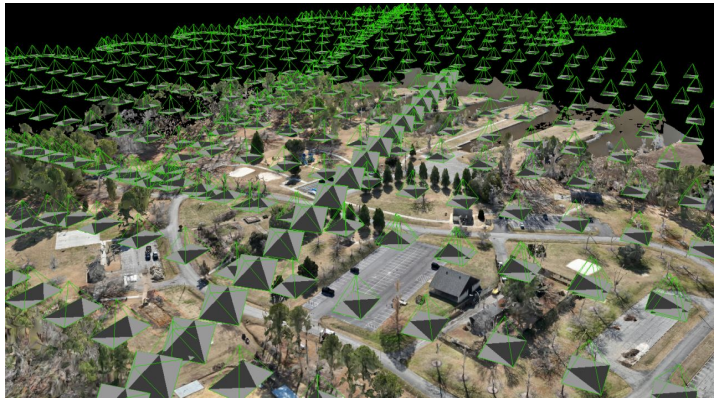
- Free and open-source.
- Cross-platform support: Available on Linux, Windows, and MacOS
- Extensive capabilities for creating and styling 2D maps.
- Integration of SAGA GIS and GRASS GIS as plugins within QGIS.
- Integration with Python: PyQGIS provides powerful tools for automating tasks and developing plugins in QGIS using Python.
- Active community support.

Data storage

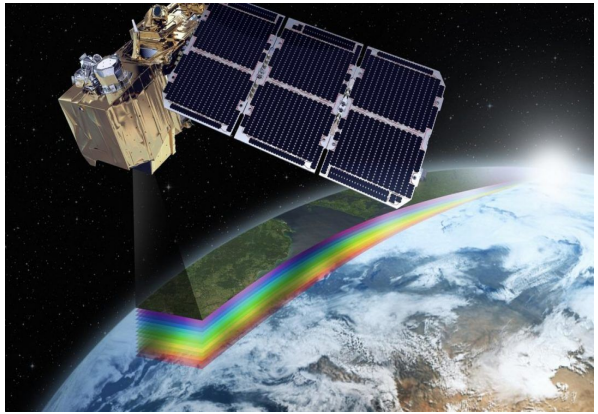
PostgreSQL database with the PostGIS extension was chosen for data storage.



Data storage

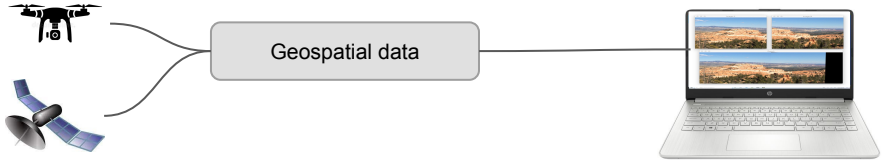


Data obtained using drones



Data obtained from satellites

Data processing: Creating panoramas

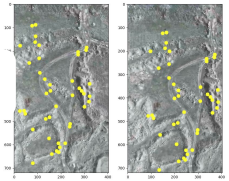


Geospatial data

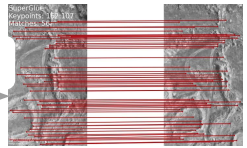
Ground station processing

Preprocessing of data

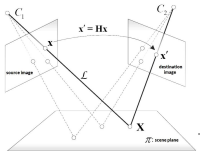
Detection of keypoints using SuperPoint

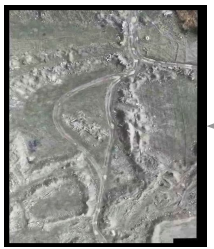


Matching keypoints using SuperGlue



Calculation of homography matrices

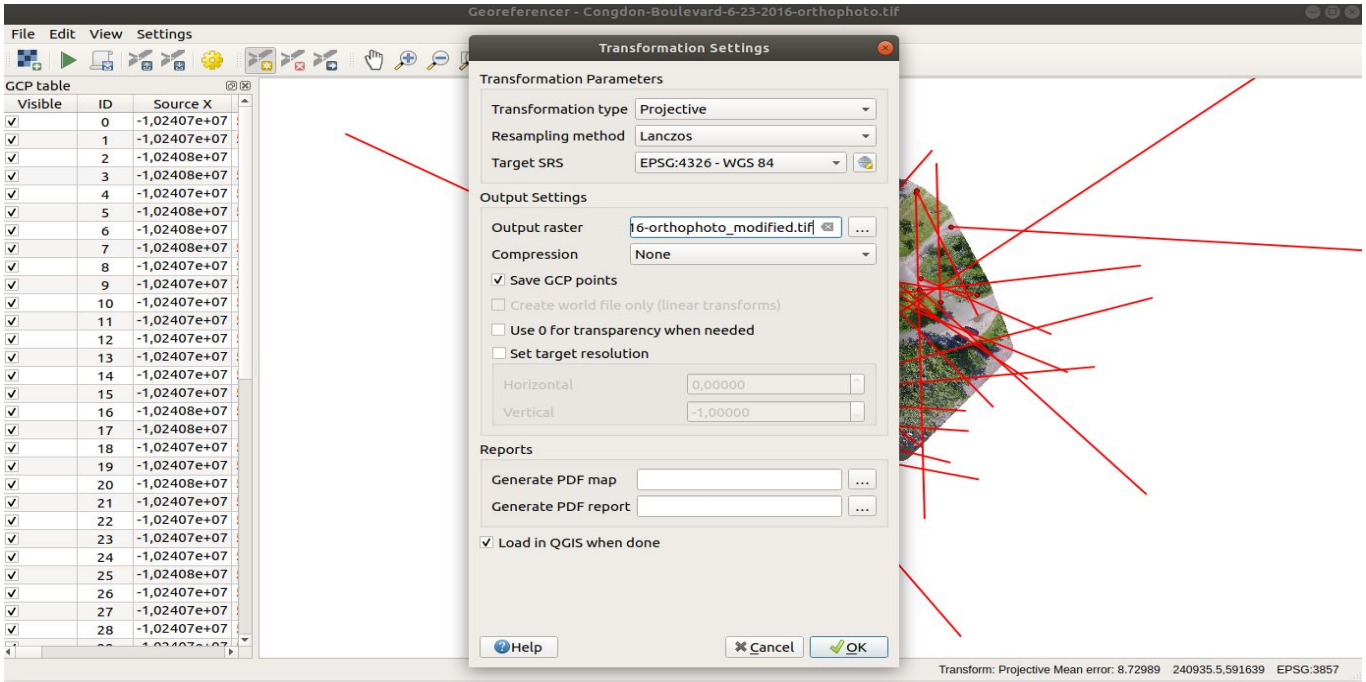




Seamless blending and panorama stitching

Image warping for alignment to a single coordinate system

Georeferencing in QGIS



Metrics for evaluation

RMSE - The RMSE is a measure of the average magnitude of the errors between predicted and actual values. (lower better)

SSIM - The SSIM is a metric that considers luminance, contrast, and structure to evaluate the similarity between two images. It takes into account the local patterns of pixel intensities.(higher better)

Results

	1	1_g	2	2_g	3	3_g	4	4_g	5	5_g
RMSE	0.172	0.153	0.246	0.163	0.204	0.178	0.203	0.194	0.187	0.18
SSIM	0.335	0.487	0.297	0.546	0.317	0.363	0.368	0.379	0.354	0.379

Table 1. Results of comparison of orthophotos with google satellite map before and after georeferencing with transformation type projected and resampling method cubic spline

Data processing: Results

The map before georeferencing

ORiginal map

The map after georeferencing

Future work

- Assemble Drone Swarm
- Path Optimization (Smoothing)
- Handling Start Points Outside Polygon
- Reinforcement Learning Training
- Data Collection and Map Quality Evaluation
- Experiments for Mapping Large Territories

Thank you for attention!

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