LOCALISATION OF UAV IN THE WILDERNESS: ADDRESSING RELIABILITY OF FEATURE MATCHING ALGORITHM

RESEARCH QUESTION: TO WHAT EXTENT IS THE VISION-BASED GNSS-FREE LOCALISATION ALGORITHM EFFECTIVE?

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Methodology

1 Initialising Code Base

- Install the vision-based localisation algorithm into Visual Studio Code
- The algorithm used was "Vision-based GNSS-free localisation of UAVS in the wild by TerboucheHacene

2 Dataset Collection

- An existing query image that was taken by UAV was used
- Reference satellite maps and the GPS coordinates of the map corners were collected

3 Algorithm Testing

- The query image was tested against numerous sets of satellite maps
- The algorithm feature matches the query to the corresponding area on the reference map, and predicts the coordinates of the query
- 4 sets of tests: Zoom level (quality) of the reference map, multiple tiles of maps, multiple tiles of maps with similar features, and tiles of maps with split features

4 Data Analysis

- Data collected was analysed

5 Conclusion

- A conclusion was established

Abstract

UAV technology has seen rapid evolution throughout the years, transforming itself into an invaluable asset for applications such as search and rescue operations, inspections, mapping and agriculture. One major challenge in these applications is the heavy reliance on GPS for a drone to effectively localise itself for UA operations. GPS is susceptible to jamming, and may not function properly in remote and non-urbanised areas, where GPS signals may be weak or completely unavailable. This paper aims to investigate the novel approach of geo-referencing satellite imagery using feature matching algorithms to enhance the localisation capabilities of drones in such environments, focusing on overcoming the limitations of traditional satellite-based navigation systems. By examining algorithms like SuperPoint and SuperGlue, we aim to assess the accuracy, reliability and efficiency of satellite imagery feature matching drone localisation, especially in the context of Singapore, in situations when GPS/GNSS is unavailable. Our findings suggest that while these intricate algorithms are capable of fabricating apt results under highly specific conditions, it faces several limitations by numerous factors such as zoom level, resolution of query and reference images, and others. This paper aims to scrutinise a UAV localisation algorithm to see if it is apt for real-world solutions, in the context of Singapore.

Objectives

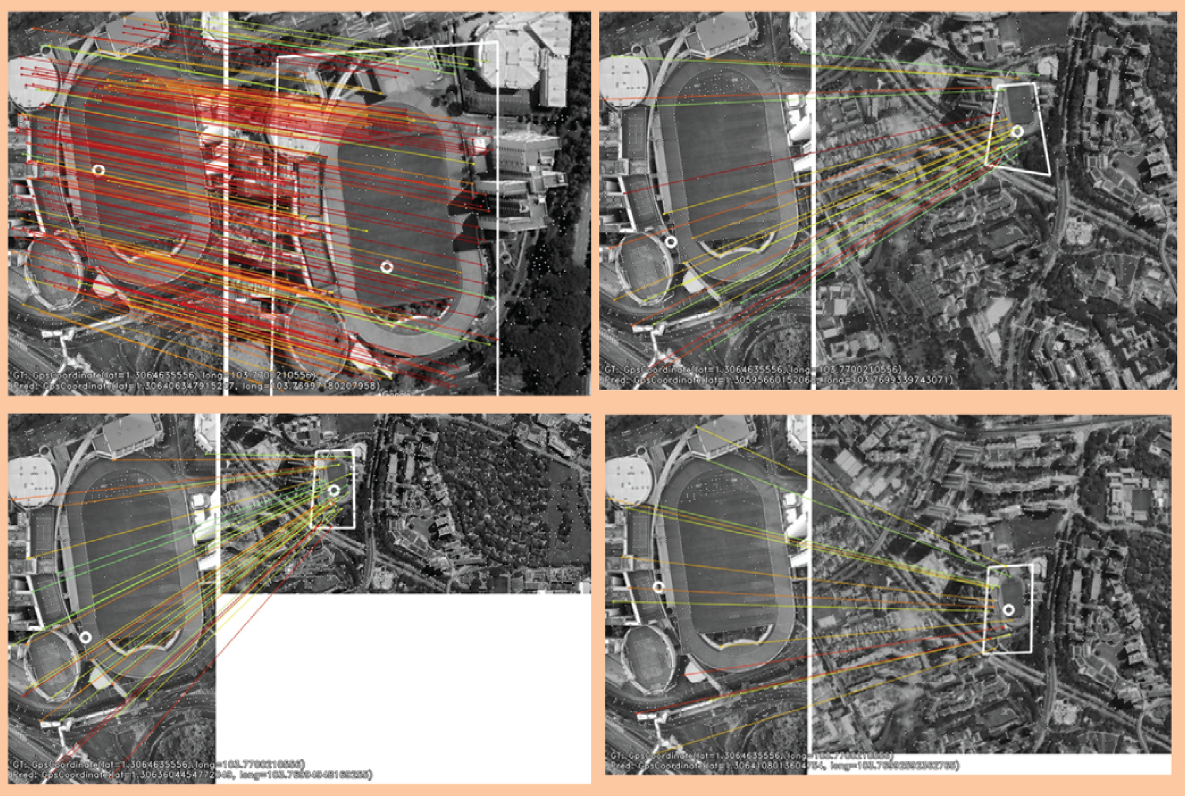
To figure out the effectiveness of the Vision-based GNSS-free localisation Algorithm through rigorous testing.

The effectiveness of a vision-based GNSS-free localisation algorithm is largely determined by:

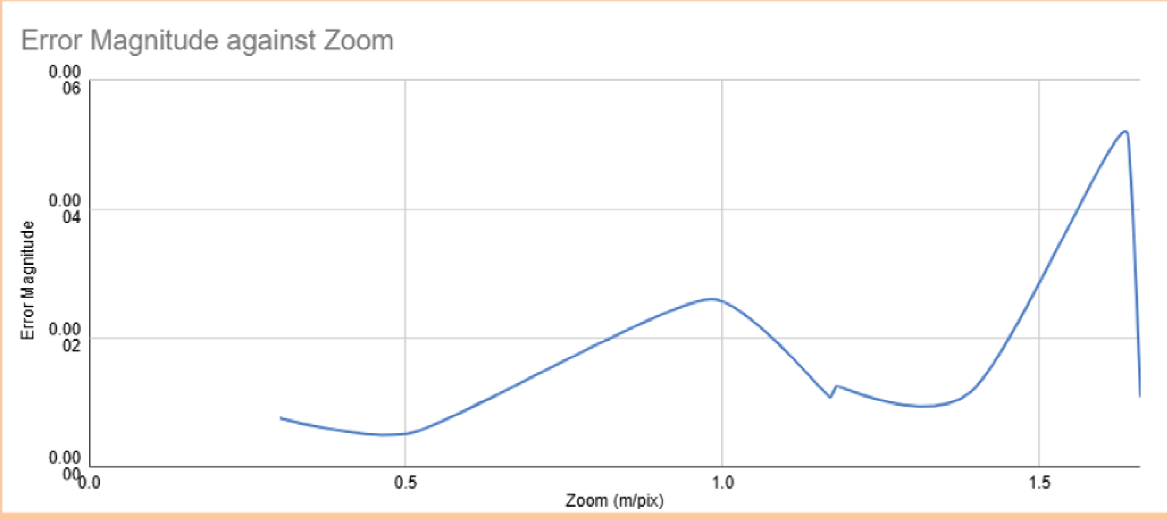
- Its ability to accurately estimate a drone's position and orientation in remote or GPS-denied areas such as forests or mountainous regions
- Depends on factors such as the quality of visual data UAV
- Flight factors
- The complexity of the terrain and the robustness of the algorithm in handling lighting changes and dynamic environments.

Results and Discussion

Zoom Level Test

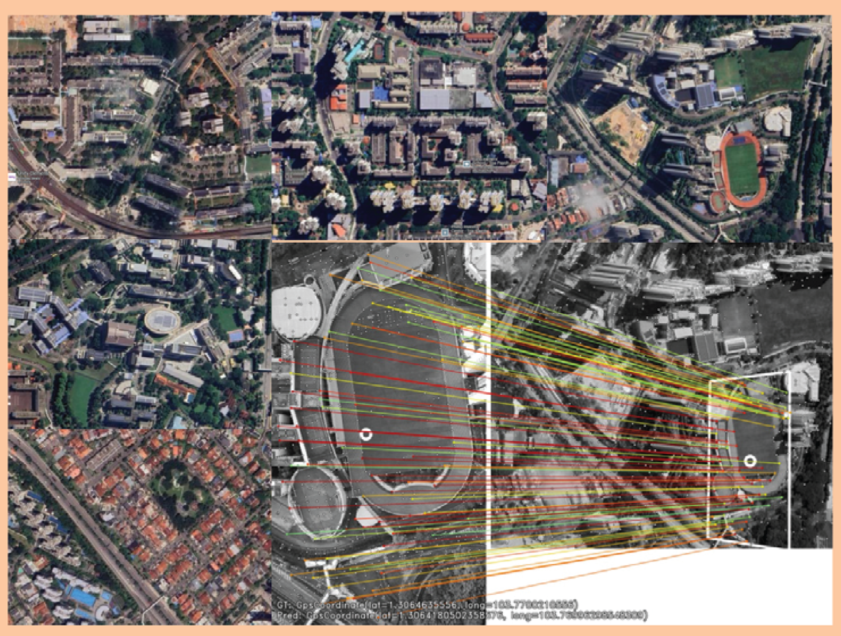


- The zoom level (quality) of the reference satellite map was varied to analyse the algorithm's response
- The magnitude of error in the algorithm's coordinate prediction (obtained from the difference in predicted latitude and longitude and the actual ground truth latitude and longitude values) was measured

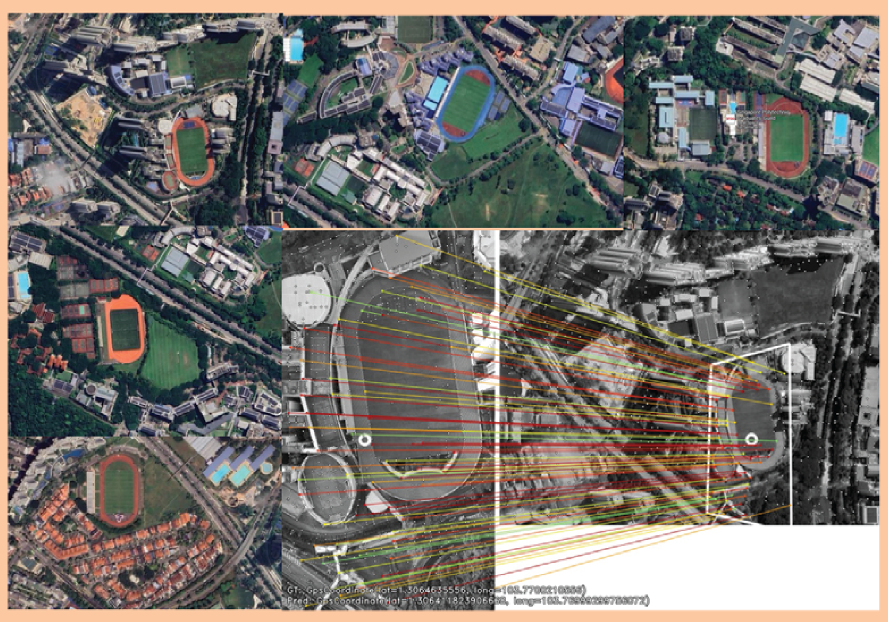


- We expected the magnitude of error to scale exponentially as the zoom level (quality) of the reference map decreases
- As seen from the images above, as zoom level increases, level of feature matching decreases. Algorithm breaks down past the zoom level of 1.7m/pix
- The results appear to somewhat match our hypothesis, although there are a couple of anomalies at the 1.0m/pix and 1.6m/pix regions, which are most likely algorithmic inconsistencies or potential human error

Multi title map test

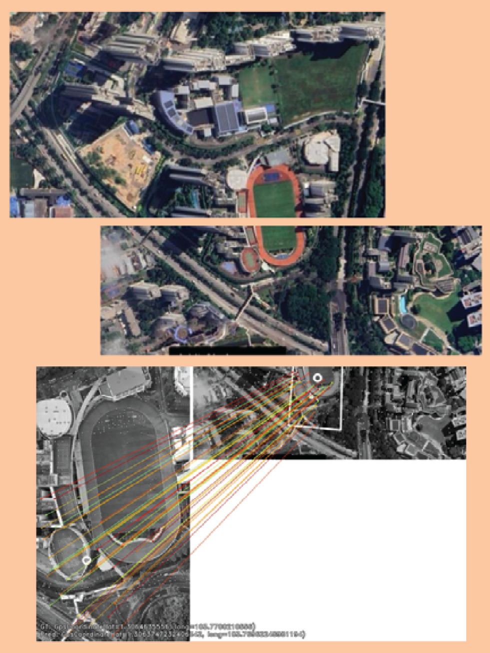


- When multiple tiles of reference maps were used, the algorithm managed to identify and feature match the correct tile
- The algorithm is considerably versatile and can scan through a larger amount of reference map data and correctly identify the area of the query and accurately predict ground truth



- When multiple tiles of reference maps with similar features were used, the algorithm managed to identify the correct tile and feature match
- The algorithm can differentiate through tiles with similar features (field+track), possibly using other features (roads/trees)

Split test map



- When the correct tile of map was split into 2, where more than 1 tile had correct areas to feature map, the program varied only the tile with the lower half of the correct map
- This phenomenon could be replicated
- It seems like the program favours certain features only found in the bottom half of the map, likely the bridges/trees/roads

Conclusion

- The algorithm could accept a certain range of quality/resolution of satellite maps (up to ~1.7m/pix zoom level), which is unfortunately rather sensitive, as maps on a larger scale usually do not offer such high quality/resolution
- The algorithm's accuracy does vary by quality of the satellite map, in a somewhat exponential relationship
- The algorithm is able to identify and match the correct map tile amongst a larger pool of numerous map tiles
- The algorithm can identify and match the correct map tile amongst a pool of similar tiles

Future Work

- Extending the scope of testing to diverse environments, to a greater range of orientation, position and zoom of the images
- Include improving real-world processing capabilities, such as considering detecting dynamic objects. This can be done by validating results under dynamic, long-duration missions to provide a deeper understanding of how these academic algorithms can be implemented in real-world scenarios and support UAV localisation in challenging, GPS-weak scenarios

References

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