Temasek Defence Systems Institute

# ASSESSMENT OF EO IMAGING TECHNOLOGY FOR UAS NAVIGATION IN A GPS-DENIED ENVIRONMENT

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## Objective

Navigation systems of unmanned aircraft systems (UAS) are heavily dependent on the availability of Global Positioning Systems (GPS). Although inertial navigation systems (INS) can provide position and velocity based on acceleration measurements, the information degrades over time and reduces capability of the UAS system. In a GPS-denied environment, a UAS must utilize alternative sensor sources for navigating. This thesis presents evaluation results on the usage of onboard down-looking electro-optical (EO) sensors and image matching techniques to assist in GPS-free navigation of aerial platforms.

## Methodology

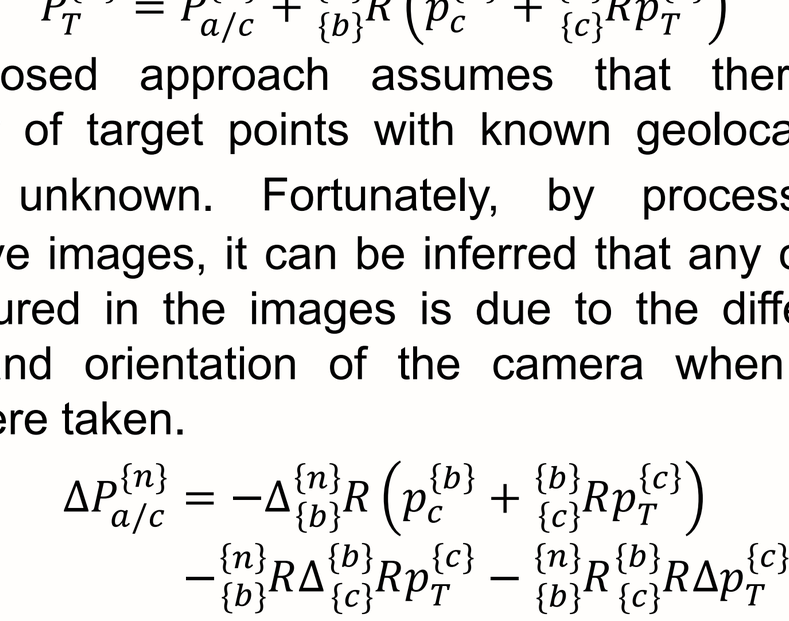
The position of a feature or any target point of interest in a local tangent coordinate plane $\{n\}$, $P_T^{\{n\}}$, can be derived from its position in the camera coordinate frame $\{c\}$, $p_T^{\{c\}}$ , through a series of transformations

$$P_T^{\{n\}} = P_{a/c}^{\{n\}} + {}^{\{n\}}_{\{b\}}R\left(p_c^{\{b\}} + {}^{\{b\}}_{\{c\}}Rp_T^{\{c\}}\right) \quad (1)$$

The proposed approach assumes that there is no availability of target points with known geolocation, i.e., $P_T^{\{n\}}$ is unknown. Fortunately, by processing two consecutive images, it can be inferred that any change in view captured in the images is due to the difference in position and orientation of the camera when the two images were taken.

$$\begin{aligned}\Delta P_{a/c}^{\{n\}} = &-\Delta^{\{n\}}_{\{b\}}R\left(p_c^{\{b\}} + {}^{\{b\}}_{\{c\}}Rp_T^{\{c\}}\right)\\ &-{}^{\{n\}}_{\{b\}}R\Delta^{\{b\}}_{\{c\}}Rp_T^{\{c\}} - {}^{\{n\}}_{\{b\}}R^{\{b\}}_{\{c\}}R\Delta p_T^{\{c\}}\end{aligned} \quad (2)$$

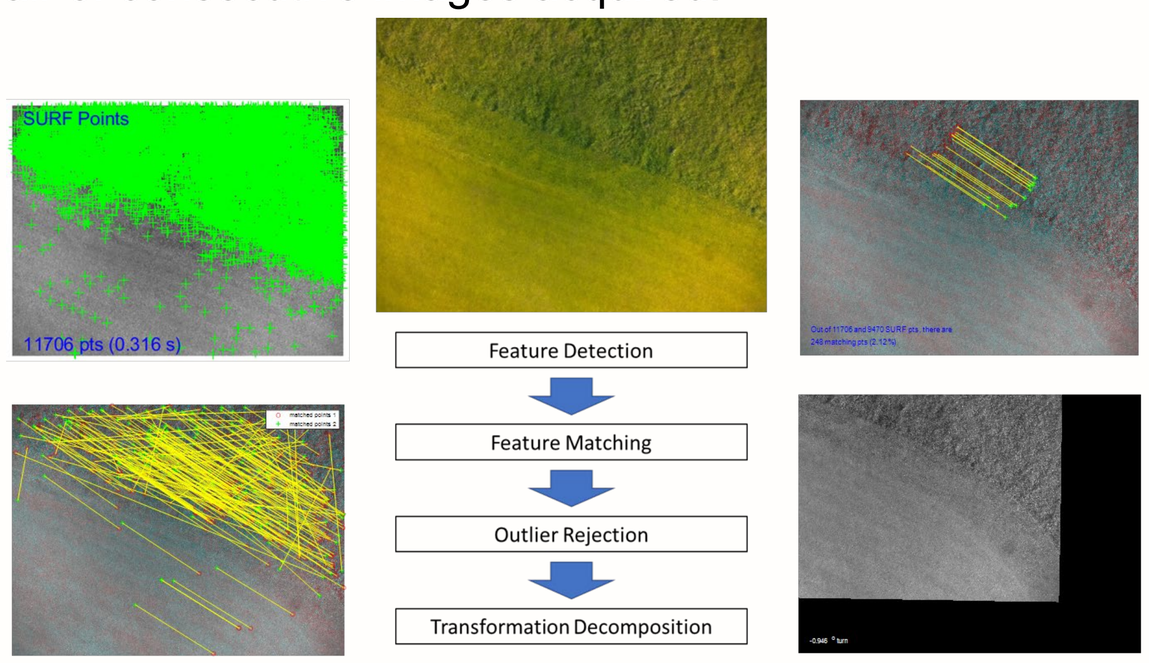
In order to be successfully implemented on UAS, the computing speed of the proposed image-matching technique is crucial; more features need to be found and matched faster.




*CPU execution time with respect to number of features detected*

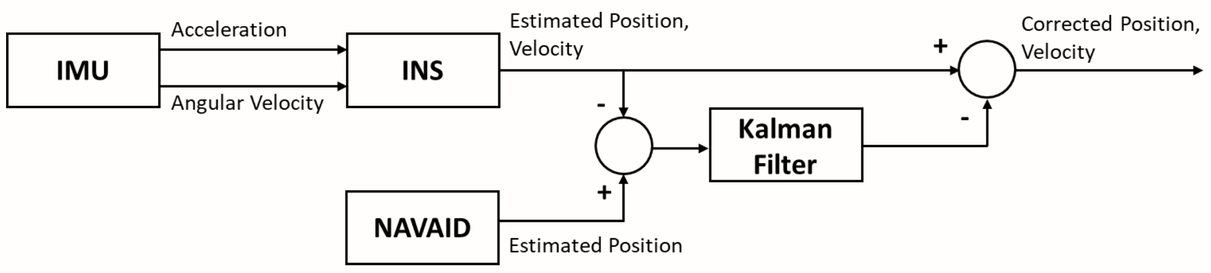
## Research Outcomes

Image processing for a vision-based navigation aid (NAVAID) were executed in the specified order on every pair of consecutive images acquired.



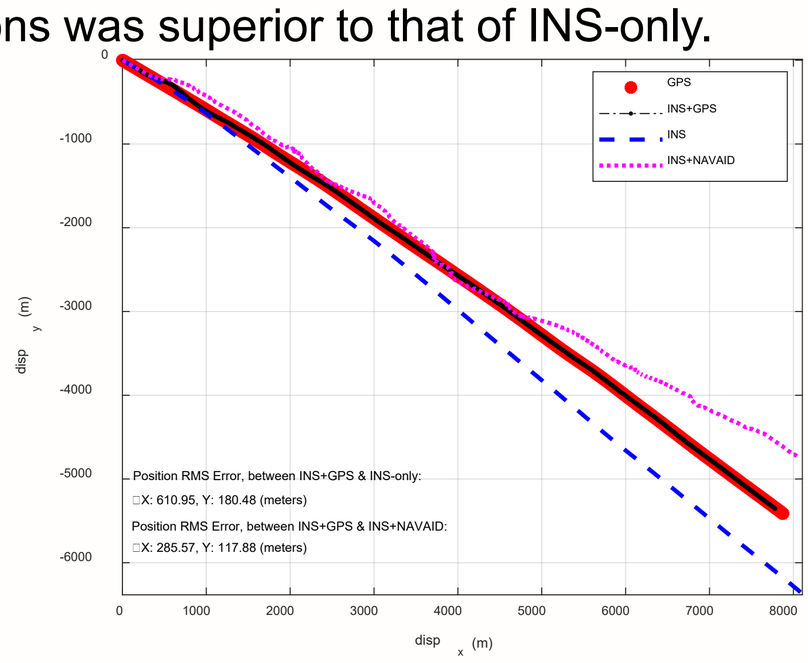

*Vision-based NAVAID image processing sequence*

When GPS signals are unavailable, the NAVAID solution provides position estimates and ensures that the UAS can continue and successfully complete its mission.




*Block diagram of INS and NAVAID integration*

Trajectory results revealed that NAVAID solution trajectory estimations was superior to that of INS-only.




*Comparison of INS-GPS, INS-only, and INS-NAVAID FAST trajectories*

## Recommendations for Future Research

- Resolve image distortion due to flight maneuvers and changing gimbal orientation to improve trajectory estimations.
- Development of new feature detection algorithms which may offer more detections in a shorter computing time.

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