Online Observability Analysis of Sliding Window Estimator for Monocular Visual Odometry on MAVs

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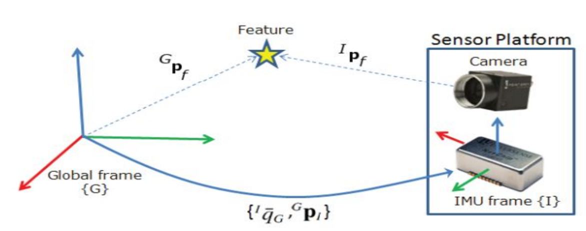
Background & Objective

- Compare to stereo visual-inertial system, monocular visual-inertial systems(VINS) are more attractive to micro aerial vehicles(MAVs) because of the lower cost and less CPU requirement.
- A sliding window filter(SWF) can be used to estimate the states over a sliding time window at a fixed time.



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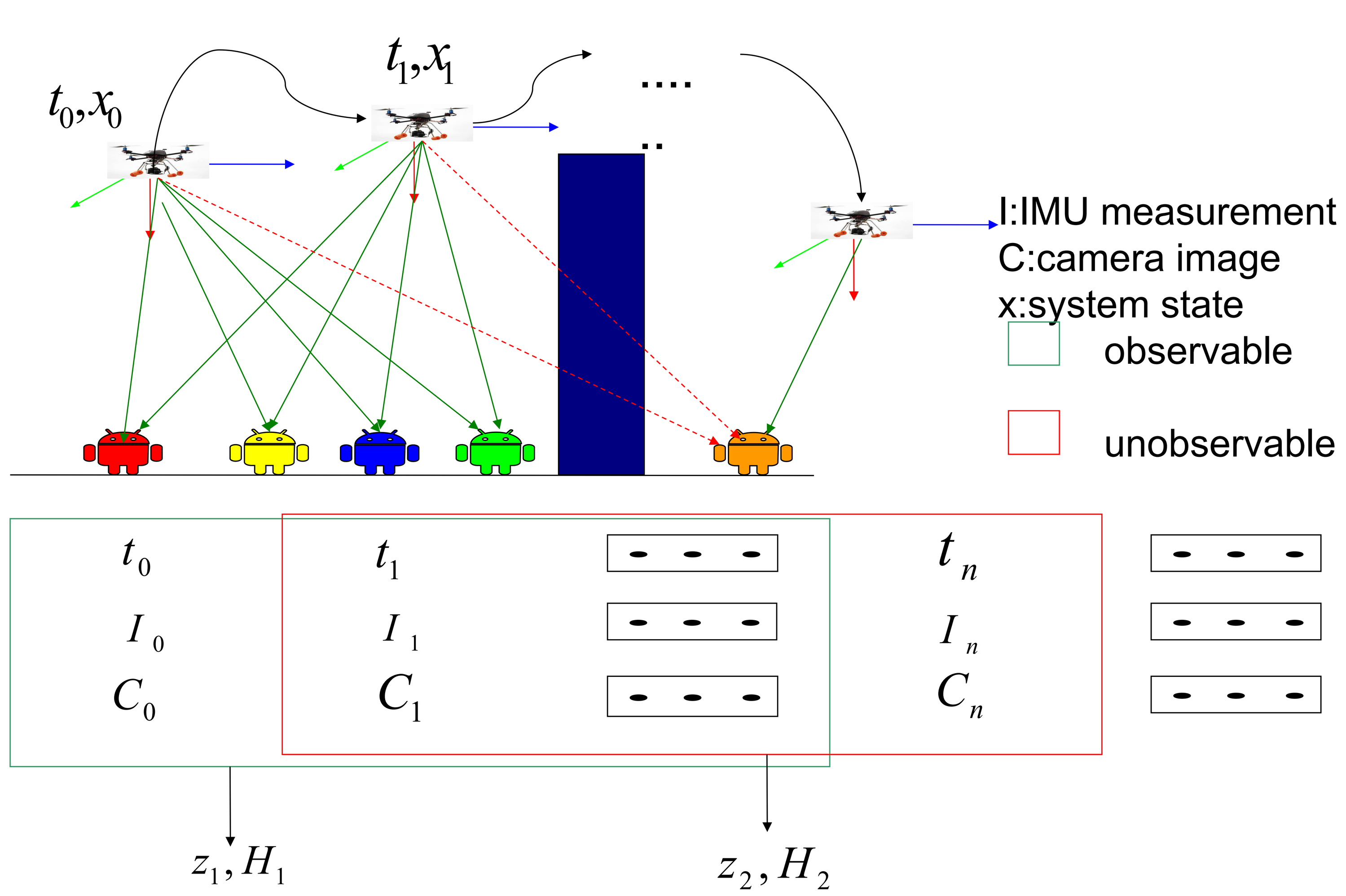
Objective: SWF can be used only when the system is obsevable. So, we need to find an online method to detect the failure or unreliable estimation by analysing the system observability and estimation sensitivity.

Linear sliding window estimator

- **Sliding window**

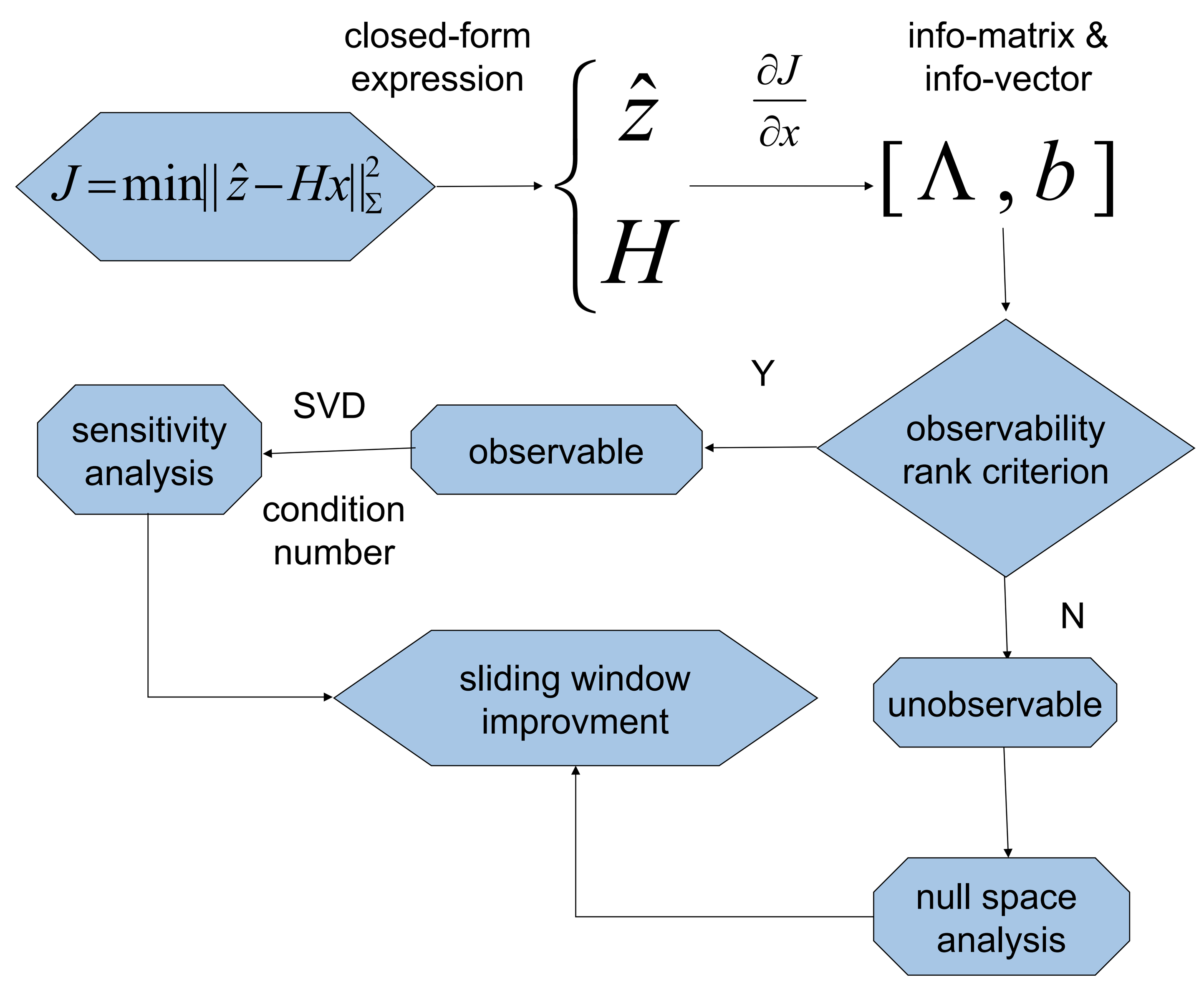


Maximum likelihood estimate criterion: $J = \min \|\hat{z} - Hx\|_\Sigma^2$

- z:measurement
- H:linear time-variant system paramenters
- x:states in sliding window

My study of observability examines whether the information provided by the available measurements is sufficient for estimating the parameters by using the estimate criterion.

Observability analysis

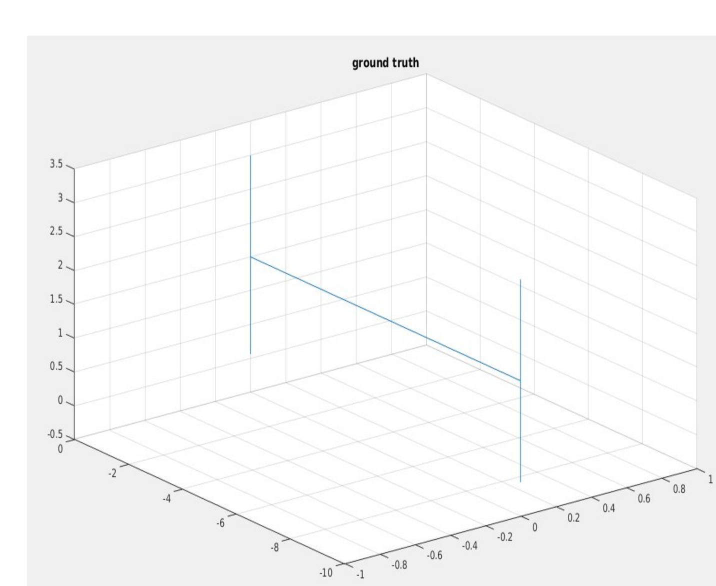


- **rank of Information matrix:** The states are observable, only when Info-matrix is full rank.
- **condition number:** Condition number is used to measure the function sensitivity to input error.lower condition number means the estiamtion is more reliable.

Simulation Results

Simulation design:

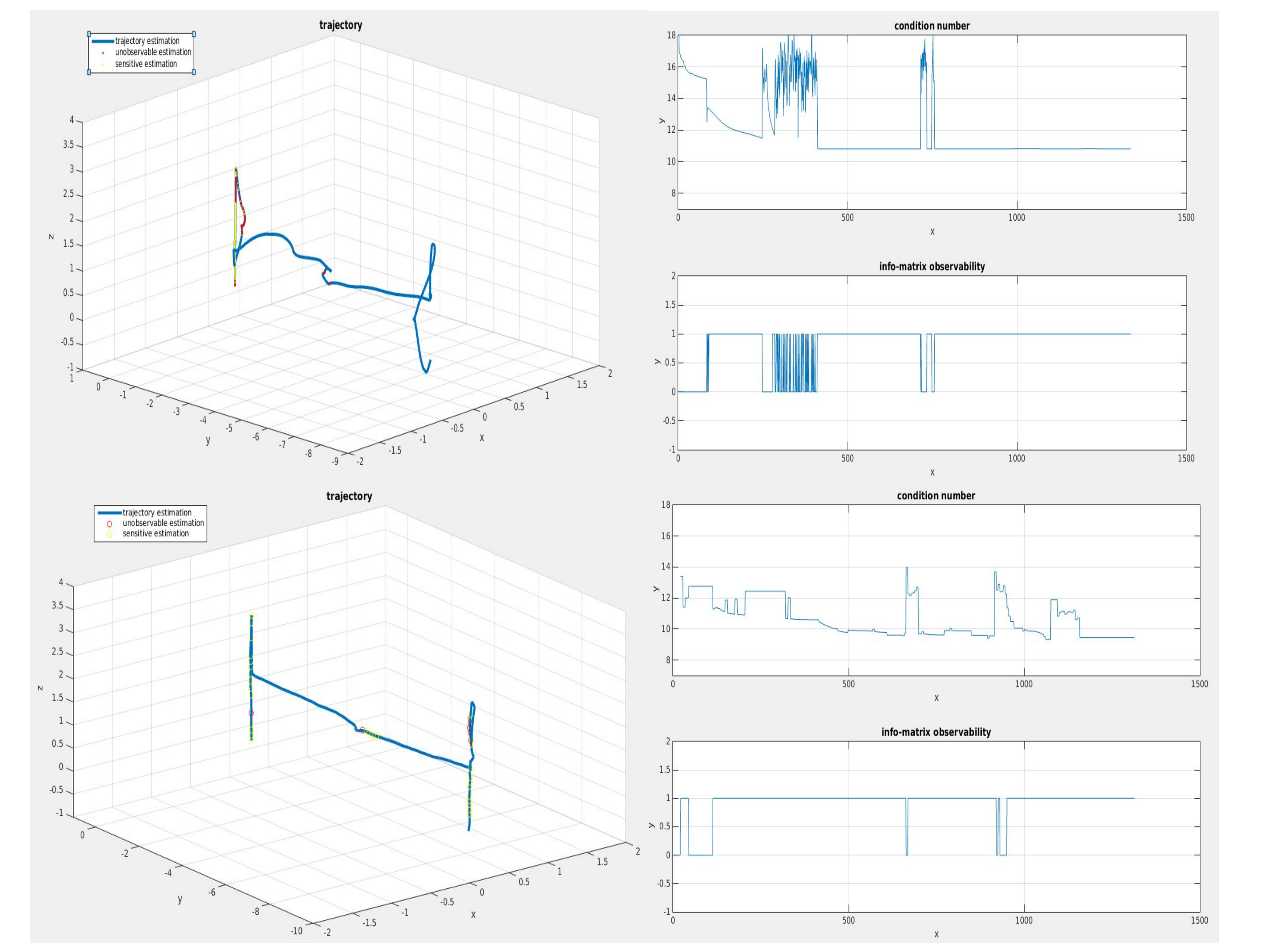
- We simulate the motion both in challenging and favorable environments to generate different estimation results



- Compare the results by analysing the observability and sensitivity.

Results:

- **condition number :** The values of condition number are logarithm.
- **info-matrix observability :** '1' represents 'observable', '0' represents 'unobservable'.



	a	b
error	6.2073	0.5534

Conclusion:
When the system is unobservable or sensitive, the estimation results will be inaccurate. My work can be used to detect the unreliability or failure when we control the MAVs.

Furture work

- Find a method to marginalize the bad states of sliding window with observability analysis results and parallax threshold.
- Find the connection between the null space of info-matrix and recovery motion.

Reference

[1] S Shen, Y Mulgaonkar, N Michael, V Kumar, " Initialization-Free Monocular Visual-InertialEstimation with Application to Autonomous MAVs"
[2] G huang, A Mourikis, S roumeliotis , "Observability-constrained Vision-aided Inertial Navigation"
[3] J Hesch, D Kottas, S Bowman, S Roumeliotis, "Camera-IMU-based localization: Observability analysis and consistency improvement"