MINIMISING LOCALISATION ERROR WITH MOBILE SENSORS FOR UAS NAVIGATION

Problem

GNSS-denied navigation remains a huge challenge for modern uncrewed aerial systems (UAS) with GNSS-denial being used to defeat these systems in current conflicts. Inexpensive inertial navigation systems (INS) suitable for UAS rapidly drift and lose track of their absolute position without additional information to assist in fixing their position. With the assistance of off-board sensors, it may be possible to direct a GNSS-denied UAS to a given location to within a threshold accuracy.

Need and relevance to Defence

The reliance on GNSS-type satellite constellations represents a single-point-of-failure for many UASs in both the civilian and military domains. Reducing reliance on this navigation method would enable (a), UASs to accomplish missions in environments in which their operation would otherwise be prevented, and (b), more effectively complete missions in a GNSS-denied environments.

Research questions

What are the optimal trajectories for *support* UAS(s) (equipped with sensors capable of providing localising information) to minimise localisation error (due to INS drift) of a *target* UAS in a GNSS-denied environment?

Expected outcomes

Modelling software that takes as inputs:

1. The (3-dimensional) *intended* trajectory of a *target* Group 1[i] UAS. The intended trajectory is the planned trajectory of the UAS without consideration of localisation error.
2. N - the number of Group 2 *support* UASs, capable of transmitting localising information to the target UAS.
3. Error parameters/characteristics of sensors located on the N support UAS and the target UAS.
4. GNSS-denied regions that are modelled as ellipsoids and/or cones.

And produces as outputs:

1. 3-dimensional trajectories of the N support UAS such that the localising error remains below a threshold for the maximum time.
2. The localising error at the end of the target UASs intended trajectory.

Figure 1 shows an example geometry of the scenario.

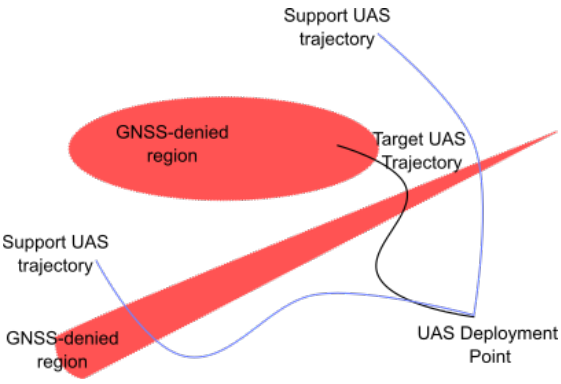

Figure 1 Example Geometry

Methodology/approach

The following assumptions/constraints can be made:

1. All UAS (target + support) trajectories start at a identical point in space.
2. The target UAS trajectory ends within a GNSS-denied region.
3. All UAS have a unicycle-type motion model.
4. Accurate altitude measurements are available to the target UAS.
5. N can take any value between 1 and (M-1) where M is the smallest number such that the solution trivialises to the ‘daisy-chain’ solution.
6. The GNSS-denied regions do not include the starting point of the UAS trajectories.
7. Communications are available, but not reliable, and must not be necessary for the target UAS to sustain flight.
8. All sensor equipment should cost below $20,000, with cost-effectiveness highly valued.
9. The target UAS is capable of housing sensors, consistent with a category 1 UAS.
10. All sensors/transmitters (other than those on the target UAS) must be capable of being housed on a category 2 UAS.
11. Active sensors on the target UAS are strongly discouraged, but not forbidden.

Other notes:

- If cognisant of the operating environment of the UAS further modelling assumptions are acceptable.
- Subject to an approval process – experimental UAS flight data can be provided.
- Python is the preferred modelling software, and Matlab is of secondary preference.

Possible Extension:

- GNSS-denied regions can be configured with a quality parameter that constrains the frequency of localising information updates.

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[i] See https://en.wikipedia.org/wiki/UAS_groups_of_the_United_States_military.