Tracking Drone Orientation with Multiple GPS Receivers

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The Problem Definition: With technology evolution there have been multiple innovations for process simplification and speed-up. One such innovation is drones. Although these tech birds have made a huge positive contribution in multiple domains (like military, cinematography, commercial purposes etc.) they are still not considered safe for responsible use in public places. Over years multiple cases of drone crashes have been reported thereby making drones less socially acceptable and preventing their free public flights. This paper presents the idea of SafetyNet, a GPS-only based system as a failsafe mechanism for drones.

Key Idea: The key idea is to install 4 GPS receivers at four corners of the drone and use these receivers for orientation and safe landing of the drone in case of Inertial Measurement Units (IMU) failure. However, the challenge with GPS-based approach is to attain the accuracy upto a few centimeters. Accuracy plays a vital role because the drones are smaller in size (ranging in centimeters) and hence precise location is needed for their 3D orientation and navigation to the base for safe landing.

Important Details: The main component in drones, which is responsible for its orientation and stability, is the Inertial Measurement Units (IMU). IMU is a consolidation of multiple sensors, (namely, accelerometers, gyroscope sensors and magnetometers) embedded on it. The output from these sensors help the flight controller make decisions for drone orientation and help in the safe flight of the drone. However, these sensors can be noisy, which can impact the drone orientation and can even lead to hazards or accidents in certain situations. The major factors that can contribute to noise of these sensors include hardware issues, vibration from the drone propellers, electromagnetic interferences etc. Although hardware issues can be resolved by introducing multiple IMUs in the drone, in order to resolve the issue of sensory noise (which can lead to IMU failure as well) GPS based approach is introduced as a failsafe mechanism.

My Thoughts and Criticism:

The techniques mentioned in the paper are well supported with relevant mathematical proofs and analysis but at some point certain assumptions are made or certain factors are ignored (for simplification), which I believe could be gaps:

1. No doubt, GPS is reliable but over years multiple accidents have been reported due to GPS interference and the reason for these interference is Multipath. In most of the mathematical proofs mentioned in the paper the noise due to Multipath is ignored. However, if we consider the drones for commercial purposes (say package delivery), then there are high chances that there can be N number of drones, belonging to M number of service providers, in limited space or in narrow streets. In this case multipath would prove to be a major concern.
2. Drones are highly used for military purposes and most of these classified areas have signal jammers which can block the GPS signals. In such cases the drones will lose the

data and can lose the navigation to the base. How will SafetyNet handle the failures in case of GPS Jammers?

3. The section *2.2 (Pseudorange)* mentions factor cti (where *ti* is the receiver clock bias), as the major source of error. We also know that installing 4 GPS receivers can highly add to the cost of the drone. Then couldn't we reduce the count of the GPS receivers in the drone and introduce an atomic clock in the limited receivers, in order to reduce the receiver's time bias.
4. Time granularity is mentioned as one of the challenges alongside accuracy/precision of the drone location. Therefore the focus should also be made to improve the computation logic of the drone's flight controller in order to be able to predict the trajectory in case of missing data (due to GPS unavailability).
5. Verification of section *"3. Single Differentials across Time"* (as mentioned) is done with the static receiver on the ground. But in real life scenarios the receiver might not be static in nature (it could be on a sailing boat, or a moving car etc.) which could result in accuracy issues.
6. GPS functioning can be considerably impacted by factors like climate and battery of the device.
7. GPS Dependency can even lead to GPS spoofing thereby resulting in security and privacy issues.