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**Tracking drone orientation with multiple GPS receivers**

Drones have a lot of applications but even then we don't see them since there have been issues with drones such as crashing. In order to prevent drones from crashing, we need to extract information about their orientation for stabilizing the drone. Inertial sensors are used to capture this very information. However, these sensors can fail and can lead to crashes.

As an alternate fail safe mechanism when the primary mode of sensing fails, the authors propose SafetyNet. So far, GPS has been used for localization. The authors propose using GPS for orientation sensing through a system called SafetyNet. Multiple receivers are placed on the drone (at each corner of the drone) to calculate the positions which are then converted to 3D orientation. In order to achieve orientation accuracy of 2 degrees, the location accuracy must be about 2cms (GPS would not work since it offers 3m accuracy which is much larger than the dimensions of a drone (0.3m)). The authors use techniques from relative GPS to reduce the errror to 15 cms.

***Spatial differentials***. Carrier phases are noisy and by performing differentials, some of the correlated errors can be eliminated. From this, we then obtain a simpler model of measuring the relative positions (say $\mathbf{R}_{12}$) between GPS receiver pairs. Performing double differentials, we are eliminating some of the more complex issues such as the unsynchronized clock errors and atmospheric delays.

Thus, the differential GPS which is based on this principle, we can get accuracy upto 15cms which is suitable for this purpose of oriental estimation of large objects. <u>But the issue still remains for a smaller objects which needs to be sorted out.</u>

***Temporal differentials***. Similar to the spatial differentials, the temporal differentials are the same equations at a particular time instant say t1 and t2 (when there is a shift of the object in question). Since the integer ambiguity has been tracked due to the Doppler shifts, the integer ambiguity is eliminated.

Spatial differentials provide a measure of relative vectors and thus the absolute orientation of the drone but it **suffers from integer ambiguity**. Temporal measure change in relative vectors and hence change in orientation but **does not suffer from the integer ambiguity.**

Since the signals of spatial and temporal differentials are noisy, a filtering approach is taken to handle any dynamic errors that may come due to the noisy signals.

In a Bayesian filtering approach, the orientation of the drone is considered as a state and with movement, the states change over time.

There exists two values of importance : A transition function which links two states and a measurement function that provides the absolute values in a particular state. The authors propose using **temporal differentials as transition function and the spatial differentials as the measurement function**.

To solve Integer ambiguity : 1. Low dynamic flights : Kalman filter approach : The orientations in different states are gaussian like and thus, a kalman filter is used to combine them.

2. Highly aggressive : due to cycle slips, the integer errors are in multiples of wavelength and thus, the kalman method does not work and hence the Particle filter approach is used.

(**This summary is till Page 6 -** As suggested by the professor)

The paper is interesting since it proposes using GPS for a **new application of orientation sensing** which can be used in other applications.

Also, with the idea proposed, the **accuracy of the GPS coordinates improves** too which would help in better mapping and open up newer opportunities.

However, there were a few points that needed more clarity :

**Questions** :

1. Would the system fail when there is lack of GPS signals due to issues such as jamming or severe weather conditions?
2. How do we make sure that the drone lands safely in such scenarios when there is no signal?

**More details about the paper**

Gowda, M., Manweiler, J., Dhekne, A., Choudhury, R. R., & Weisz, J. D. (2016, October). Tracking drone orientation with multiple GPS receivers. In *Proceedings of the 22nd annual international conference on mobile computing and networking* (pp. 280-293).