Modeling errors and implications of zero-velocity-updates for pedestrian navigation

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ABSTRACT

Zero-velocity updates (ZUPTs) combined with a foot-mounted inertial navigation system (INS) has been shown to have the capability to provide accurate and reliable pedestrian dead-reckoning. However, the customary Kalman type of filter implementation implicitly make the assumption that the velocity errors provided by the ZUPTs are either zero, or zero-mean and white. In reality, these assumptions will seldom hold perfectly and the resulting modeling errors introduces systematic errors and pose a fundamental performance limiting factor for ZUPTs applied by standard Kalman filter measurement updates. In this paper we examine and quantify these errors and limits.

For benign gait and multistep trajectories, the introduced systematic errors are normally small and not easily separable, in terms of mean position error, from errors induced by the inertial measurement errors. Instead to assess the modeling errors we consider the temporal distribution of ZUPT residuals and concurrent inertial measurements and zero-velocity test statistics. In turn, the introduced systematic errors are quantified by the impact on the position estimates of individual trajectories given by different zero-velocity detections. A number of systematic errors can easily be observed. For example, for walk and running motion, the ZUPTs cut the steps short. This gives a bias in the relative position estimates for each step pulling the estimate upward and backward. For running, a systematic rotation can be observed during the ZUPTs. If sensor biases are modeled, this can introduce significant heading errors. The systematic errors are seen to worsen with a poor inertial sensor mounting point.

In conclusion, the ZUPTs applied by standard Kalman measurement updates are shown to introduce systematic errors. Among other things, this imply that we should be careful with modeling sensor errors and that alternative to standard Kalman measurement updates should be considered.

KEYWORDS: Zero-velocity-update, inertial navigation, modeling errors.