Analysis of ATD Accelerometer Data through Kalman Filtering

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ABSTRACT

Acceleration arrays, most commonly in a 3-2-2-2 arrangement, are widely used in ATD's to measure impact accelerations. Such accelerometer arrays enable the computation of the angular acceleration from instantaneous data alone, i.e., not from data taken at the previous time step. Angular velocities, though, are typically estimated by integrating these data, so the individual errors in the angular acceleration calculations accumulate over time, causing drift in the angular velocity estimates. An alternative approach for which the error is stable over time is to estimate the angular velocity from the square root of the centripetal acceleration. This method, however, exhibits inaccuracies when the magnitude of the angular velocity approaches zero. A combination of the two approaches can produce more accurate angular velocity estimates than either one individually if the relative weighting is informed by the error propagation. This paper examines whether the time scales in typical impact scenarios are long enough that such a combined approach yields significantly different angular velocity estimates than the integration approach alone. Knowing the orders of magnitude of the angular jerk, the bias errors, and the noise errors, an extended Kalman filter is implemented to combine the angular velocity estimates from the integration and centripetal acceleration approaches. This methodology is applied to ATD accelerometer array data from crash tests found in the NHTSA Vehicle Crash Test Database. The differences between the combined and individual approaches are examined in terms of the various crash test time durations. Ultimately, recommendations are made regarding the impact conditions under which the additional computation of the combined approach is justified by the improved accuracy of the angular velocity estimates. This gain in accuracy is particularly important for consideration of brain injury metrics based on peak angular velocity and peak change in angular velocity.