Using a Kalman Filter for hybridizing quantum and classical accelerometers

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Atom interferometers are low bias and low noise inertial sensors and as such have been proposed for the next generation of inertial navigation systems. In a gravimeter configuration, accuracies in the range of 1-10 ng have been achieved. However, atom interferometer suffer from low repetition rates and dead times. On the contrary, mechanical accelerometers possess broad bandwidths compatible with navigation applications, but suffer from slow bias and scale factor drifts. These two types of sensors can thus be hybridized in order to benefit from the best of both worlds: the continuous acquisition of a classical sensor and the accuracy of an atom interferometer. %Low noise seismometers have been used to improve the sensitivity of atomic gravimeters in noisy environments. The high frequency seismic noise can be rejected either using an active isolation platform. There, only the AC acceleration is used to reject the seismic phase noise and the DC part is usually discarded. %However, for navigation applications, the DC part of the acceleration contains relevant information. The atom interferometer can instead be used to track the bias drifts of the classical sensor. In a mobile application, difficulties can stem from variations of the interferometer contrast and offset. Furthermore, the inertial phase is effectively randomized by vibrations which prevents the use of phase modulation schemes. We present an approach based on a non-linear Kalman filter that is used to optimally track all the interferometer parameters making the estimation of the accelerometer bias robust against drifts of the experimental setup. We show that the hybridization procedure acts as a first order high-pass filter on the errors of the mechanical sensor, effectively removing slow bias drifts. We simulate in the laboratory a mobile environment by adding simultaneously seismic noise, temperature variations and laser intensity fluctuations. Even in these harsh conditions, we are able to track the accelerometer bias to less than µg in 200 s and 30 ng after 3 hours of integration.