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Assessing a 6C Kalman filter using experimental datasets from an industrial robot

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Current best practice in monitoring earthquake strong motion are dense networks comprising strong motion accelerometers that measure acceleration over a broad frequency and amplitude range. These instruments are capable of measuring translational motions of large earthquakes, but lack sensitivity to very low frequencies or permanent displacements. However, it is widely accepted that during earthquakes the rotational component of the ground motion, both static and dynamic, is large enough to contaminate the derived displacements from these sensors. Modern rotational sensors, are also very broadband, have a large dynamic range, and are not sensitive to translational motions. We explore the value of complementing accelerometers with these rotational sensors at seismic strong motion monitoring stations.

The assessment of the errors introduced into accelerometer records from rotational ground motions is only possible with co-located rotational instruments sensitive enough to record the small rotation rates accompanying the translational motion. Operating accelerometers alongside gyros and additionally GNSS instrumentation should allow us to record the full 6 components (6C) of near-field earthquake motions, with increasing fidelity across a very broad frequency band for the strongest motions.

We aim to demonstrate how, using a combination of the three sensor types, we can recover the full 6C ground motion, and hence also more reliable displacement records, using a versatile industrial six-axis robot that can produce controlled and repeatable 6C motion across a broad frequency band. Through the precise feedback loop used by the robot to stabilize its precise trajectory, we get a 6C recording of the driven motion represented by Euler rotations and displacements, which we use as ground truth. By simulating a combination of translational and rotational motions on the robot, we show that the 6C Kalman filter can accurately reproduce the clean simulated translational motion. By using a Kalman filter, we attempt to combine the different data sets using prediction and weighting of the observation data for an optimal solution. Our methodology tries to take into account the strengths and weaknesses of the individual instruments that are providing partly redundant and partly complementary ground motion information.