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Title of article: Testing accelerometer, GNSS and rotation sensors for strong ground motions on an industrial robot arm

Yara Rossi (1,2),
Markus Rothacher (1),
John Clinton (2),
Cédric Schmelzbach (3)

1) Institute of Geodesy and Photogrammetry, ETH Zurich, Switzerland. rossiy@ethz.ch
2) Swiss Seismological Service, ETH Zurich, Switzerland.
3) Institute of Geophysics, ETH Zurich, Switzerland.

Current best practice in monitoring earthquake strong motions are dense networks deploying strong motion accelerometers that measure acceleration over a broad frequency range. These instruments are capable of measuring translational motions of large earthquakes. Since they are inertial sensors, they are insensitive to very low frequencies or permanent displacements and are biased by rotational motion of the ground. Modern rotational sensors are very broadband, too, have a large dynamic range, but do not saturate and are not sensitive to translational motion. In addition, with recent developments in GNSS instrumentation and data processing, sub-centimeter precision in displacement is available in real-time at frequencies up to about 5-10 Hz. Thus, the co-location of rotational and GNSS instruments alongside accelerometers would allow us to record the full 6C near-field earthquake motions, with increasing fidelity across a very broad frequency band for the strongest motions. These strong ground motions are the most important records we can measure, but unfortunately, single accelerometer stations are susceptible to errors. The combination of the three instruments into a next-generation monitoring station is a new concept that we are testing using an industrial six-axis robot that can produce controlled and repeatable 6C earthquake motions. The robot is capable of performing its motions with a high pose repeatability of ±0.03 mm, due to its calibration with our own methodology and instrumentation. The three different instruments are placed on a platform mounted on the robot arm, while various broadband motions are performed. The robot simultaneously records its own motion in a feedback loop to stabilize the performed trajectory. We use this 6C feedback recording as ground truth when interpreting the different instrument data.

We intend to develop a novel acquisition and processing method to combine accelerometer, GNSS and rotation data, which will be verified using this experimental setup. 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 will take into account the strengths and weaknesses of the individual instruments that are providing partly redundant and partly complementary ground motion information.