Imaging of Six-Degree-of-Freedom in Seismic and Structural Motions

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Looking at a new view of earthquake motion

Abstract
The goal of this project was to visualize the rotational motion component of earthquakes in addition to the translational aspect. To do this we gathered data from a variety of sources including explosion data, real-time earthquake data, and shake table simulations. In gathering the data we used a variety of sensors including the R1 rotational rate sensor, accelerometers, and Metrozet’s new 6 Degree of Freedom sensor. The acceleration’s were integrated and filtered to determine displacements, which were then modeled in Matlab and Anim8or and checked against direct-displacement measurements.

Why now
• Sensor Technology has developed and become more sensitive to small rotational motions
• 10-100x stronger rotational motions than predicted
• Important for structural design safety and comprehensive building codes
• Rotations affect the measurements of translational motions

Materials and Methods
- Matlab (Math processing program) and Blast Data
- Anim8or (Animation Software)
- 6DOF (6 Degree of Freedom) Sensors
- Q330 (Data Acquisition Unit)
- Uniaxial Sensors, Triaxial Sensors, and Accelerometers
- LVDTs (Linear Variable Differential Transformer)
- Use Matlab to integrate and filter sensor data to get actual motions

Measure     Compare     Visualize

What does the true motion of an earthquake look like, and how can we accurately measure it

Visualize Some 6 DOF motion
• Began with underground blast data readily available to work out a clean filter and integration
• Wrote Matlab code using 24 equations such as
  \[ V1x = x+2^0.5*\sin(45-\text{roty})-1+2^0.5*\cos(45-\text{rotz}) \]
to animate the motion of a rigid cube who’s center point’s movement follows animation
  • After this process was refined we looked at the motion of several actual earthquakes using data from the garner valley Array
  • We also worked with team Shakes-A-Lot to instrument a pedestrian bridge to understand the rotations of actual structures under standard loads.
• Finally we built a small PVC structure, which was attached to a shake table. It was then instrumented with LVDTs as well as the Metrozet 6 DOF sensor. This allowed us to directly measure displacement as well the accelerations which we typically have to integrate into displacements to check the validity of the filter and ensure the process accuracy.
• The error between the LVDT-calculated and the Metrozet-measured rotations was on the order of a tenth of a percent, mostly due to the noise of the instruments and synchronization errors.

Further Study
• Look into the visualization of non rigid bodies and structures undergoing rotational motion
• Compare service load rotations to earthquake rotations to better understand their effect

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