Statement of Research Interests

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My research interests span the disciplines of seismology and civil engineering. I am a doctoral candidate in civil engineering with a minor in geophysics. Some areas of study in which I have significant experience are real-time seismology, inverse problems, and waveform modeling. I would like to extend the scope of my research, and am particularly interested in addressing questions in seismology or engineering that lend themselves to, or can benefit from, statistical and probabilistic approaches, such as seismic early warning, seismic hazard assessment, prediction of strong ground motion, stochastic ground motion modeling, and source verification.

The continued evolution of seismic instrumentation in recent years has resulted in an ever-increasing volume of high-quality seismic data from a large range of physical phenomena. In my research with Dr. Thomas Heaton at Caltech, I characterized the average properties of earthquake ground motion envelopes over a wide range of magnitude, distance, geological site condition, and frequency. I developed a set of attenuation relationships that describe the expected ground motion envelope amplitudes as functions of time, magnitude, and distance of 9 components (1 vertical and 2 horizontal channels for each of acceleration, velocity, and displacement) of ground motion. These attenuation relationships are derived from over 30,000 observed ground motion records and are valid up to distances 200 km away from events in the magnitude range M2.0 through M7.5. They represent one of the first attempts to characterize the average properties of the large, extremely rich dataset recorded by the California Integrated Seismic Network (CISN, formerly TriNet) in Southern California. There are a number of interesting questions to which we can apply these attenuation relationships. Mapping deviations of these ground motion averages to their causative factors can perhaps lead toward better differentiation between source, propagation, and local site effects by providing us additional insights into how observed ground motions are affected by factors such as source-to-station paths, basin amplification, local nonlinear soil response, and source or faulting type. For example, in the area of verification seismology, knowing quantitatively what average earthquake ground motions look like should allow us to say, with some quantitative degree of belief, whether new observations are from earthquakes, explosions, or other types of seismic sources. In the area of seismic early warning, where data is processed during the earthquake rupture with the goal of providing short-term warning to areas about to experience strong shaking, we can make statements about the probability of the size and location of the event, given the available observations and our knowledge of the character of average ground motion as functions of magnitude and distance.

In general, I would like to steer my future research efforts towards questions in seismology and engineering that lend themselves to statistical and probabilistic approaches. Thus, I am interested in both real-time and verification seismology. I am also interested in broadening the scope of my research to areas such as seismic hazard assessment, prediction of strong ground motion, stochastic modeling of ground motion, and source verification. Within this context, one of my long-term goals as a seismologist is to gain and contribute towards a deeper understanding of earthquake physics, seismic sources, scaling relationships, and response of the earth to different
types of excitation by examining the ever-expanding volume of modern broadband data available to scientists. As a civil engineer, I would like to apply the insights and techniques gained from such studies to help our communities better prepare for and mitigate the damage from earthquakes and other natural phenomena.

**Seismic Early Warning**

For my doctoral dissertation, I addressed one of the fundamental questions in seismic early warning: given the available (and most likely incomplete) observations from an on-going rupture, how well can we estimate magnitude and location, and how do we let incoming data modify these estimates? This study used 1-second maximum amplitude envelopes of ground motion, since these are typically the data streams that arrive at the network central processing station closest to real-time. Inspired by how experienced seismologists are able to quickly estimate magnitude and distance via visual examination of the overall shapes and frequency content of recorded seismograms, I found that using ratios of different components of ground motion (such as acceleration to displacement), in conjunction with the absolute amplitudes, allows us to resolve the magnitude-distance trade-off that is the crux of the problem in amplitude-based event-association. I developed a Bayesian method for determining the most probable estimates of magnitude and location, given the available observations and knowledge of the expected amplitude levels as functions of time, magnitude, and distance. A Bayesian approach is well suited to this type of real-time estimation problem; the sequential nature of Bayesian analysis means that estimates based on analyzing the data as they arrive approach the solution one would get if one analyzed the complete set of observations at the end of the earthquake.

I believe this type of approach has potential applications in the area of verification seismology, particularly in automatically distinguishing between earthquakes and explosions, with implications in removing chemical blasts from earthquake catalogues and nuclear test ban monitoring. It would be interesting to quantify, in a manner similar to earthquake data, the existing database of records from nuclear and chemical explosions. Statistical methods could then be used to find parameters (or combinations of parameters) that are significantly different for natural earthquakes and explosions, thus determining candidate diagnostics to distinguish between these seismic sources. A Bayesian approach could then be formulated, providing quantitative probabilities that the observations are either from an earthquake or explosion, given the observations and the models of data from the different types of sources. I believe a similar approach can also be developed for earthquake or volcanic eruption forecasting based on monitoring seismicity levels.

**New Attenuation Relationships**

The Bayesian approach to seismic early warning described above strongly relies on having good models describing how envelopes of different components of ground motions vary as functions of magnitude, distance, and time. In order to facilitate the development of this approach, I 1) compiled an extensive database of over 30,000 records from M2.0 through M7.3 Southern California events recorded on the broadband CISN network as well as other strong motion networks, 2) developed a parameterization that decomposed the 1-second envelopes of each of
these records into independent P-wave, S-wave, and ambient noise envelopes, with each of the body wave envelopes described by a rise time, a constant amplitude, a duration, and a decay parameter, and 3) developed attenuation (and hence predictive) relationships describing the magnitude, distance, and station dependence of these various parameters for both P- and S-waves for 9 channels (1 vertical and 2 horizontal components for each of acceleration, velocity, and displacement) of ground motion.

Using both broadband and strong motion data, these new attenuation relationships are valid over a larger range of magnitude (M2.0 and above) than existing strong motion relationships, which are typically valid for M5.0 and greater. They are necessarily nonlinear, to allow for the saturation of ground motion amplitudes in close to large events that has been observed in acceleration, and that has been predicted by simple scaling relations to be present to a lesser degree in velocity and displacement. These new attenuation relationships capture the different degrees of amplitude saturation in acceleration, velocity, and displacement, and have proven to be a useful tool in studying how ratios of ground motion are diagnostic of magnitude. For example, these relationships hint that, on average, the ratio of vertical acceleration to horizontal displacement is a strong indicator of magnitude, and is relatively constant up to 50 km away from the source, a characteristic that was subsequently found to hold for the observations.

While attenuation relationships valid for as small as M2.0 events may be of marginal interest to the engineering community, I believe they can be very useful to seismologists. With the ever-increasing amount of data recorded by modern seismic networks, it is impossible to examine and analyze every single record. These new ground motion parameterizations and attenuation relationships can be a useful tool for seismologists to characterize the average properties of this important data set. Having a quantitative description of what average earthquake-generated ground motions look like is crucial in developing automated algorithms for seismic early warning and verification seismology.

**Future Research**

In general, I am interested in approaching new research problems in seismology or engineering from a statistical or probabilistic perspective. My areas of strong expertise are real-time seismology, inverse problems, and waveform modeling. However, I would like to broaden the scope of my research to different areas within seismology, such as hazard assessment, stochastic ground motion modeling, prediction of strong ground motion, and seismic source verification.

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