Spatial Analysis of Landslide Hazards

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Introduction:
Landslides are one of the most damaging collateral hazards associated with earthquakes. Damage from earthquake triggered landslides has sometimes exceeded damage directly related to strong shaking and fault rupture. Seismically triggered landslides damage and destroy homes and other structures, block roads, sever pipelines and other utility lifelines, and block stream drainages. Estimating where and in what shaking conditions earthquakes are likely to trigger landslides is a key element in regional seismic hazard assessment.

The aim of this research project is to develop a GIS based probabilistic method for computing the seismic response of natural slopes within a vulnerable region taking into account the variability and uncertainty in ground condition and earthquake motion across the region.

Methodology:

- Instead of using a 1-D grid based classical approach, 2-D slope profiles are used to calculate the seismic response of slopes.
- A GIS-based methodology is developed to automatically delineate the 2-D slope profiles from DEM for a particular region.
- The seismic response of 2-D slopes are simulated using a finite difference program called FLAC.
- For a regional earthquake triggered landslide hazard analysis, to analyze a vast number of different slope profiles with different material properties and earthquake motions would require unfeasibly large numbers of FLAC runs.
- In order to overcome this problem, metamodels (or surrogate models) based on the data obtained from computer experiments are created and computationally inexpensive predictions based on these metamodels are used.

Soft Computing Methods:
In many demanding engineering applications, computationally expensive predictions based on metamodels can be used, rather than solving a set of mathematical equations numerically. In this solution, design variables are carefully chosen using design of experiments (DOE) methodology to cover a predetermined range of values and computer experiments are performed at these chosen points. The design variables and the responses from the computer simulations are then combined to construct functional relationships (metamodels) between the inputs and the outputs. Support Vector Machines (SVM) and Artificial Neural Networks (ANN) are used to create metamodels.

In general, constructing metamodels consists of four main steps:
1) Choosing an appropriate experimental design for creating input parameters for the computer simulations (Design of Experiments).
2) Running computer simulations for the selected design points and calculating the responses.
3) Choosing a model to represent the observed data and fitting the model to the data.
4) Validating the model.

Numerical Simulations:
This study utilized FLAC for seismic response simulation of slopes. FLAC (Fast Lagrangian Analysis of Continua) is an explicit finite difference program and uses a fully nonlinear analysis method for dynamic problems.

Design of Experiments: Other than the choice of metamodeling method, the accuracy and efficiency of the metamodels are determined by the experimental design used to select the input design variables. Properly designed experiments are crucial for effective metamodel building. The statistical method of Latin hypercube sampling (LHS) was used to generate a distribution of plausible collections of parameter values from a multidimensional distribution. The parameters selected, includes the inclination of slope, the height of the slope, the friction angle of soil, the density of soil, the cohesion of soil and the shear wave velocity of the soil. Earthquake magnitude (Mw) and distance from the epicenter of the earthquake (R) are chosen as strong motion design variables. The artificial earthquake records are created using SMSIM (Boore, 2000) for given magnitude and distance combinations.

2-D Slope Profile Delineation:
A GIS-based methodology using ArcHydro tools is developed to automatically delineate the 2-D slope profiles from DEM.
- The procedure consists of delineating watersheds using both normal and reverse DEM’s and using the union polygons as slope units.
- Different slope profiles are created from each slope unit and stored in a geospatial database which includes, slope height, slope angle, slope type, material properties and seismic parameters.