A New Approach to Liquefaction Potential Mapping Using Remote Sensing and Machine Learning

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Introduction:

Earthquake induced ground shaking in areas with saturated sandy soils pose a major threat to communities as a result of the soil liquefaction. Liquefaction can result in bearing capacity failures, settlements, and slope instability of soil due to increased pore pressure resulting from dynamic loading. It is important to use innovations in science and technology to improve our techniques for mapping the spatial extents of seismic hazards in order to help communities to better plan and mitigate earthquake effects. In this study we use a new approach to characterize the liquefaction potential of northern Monterey and southern Santa Cruz counties in California using satellite remote sensing and machine learning/artificial intelligence techniques. It is observed from fig 1 that the level of earthquake hazard of the study area is extremely high.

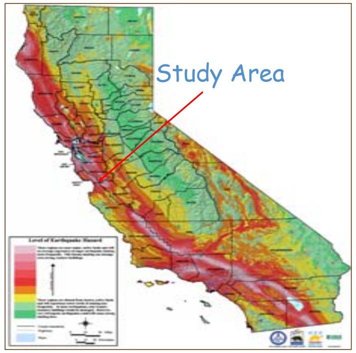

Figure 1: Levels of earthquake hazard for California (Source: http://www.seismic.ca.gov/pub/shaking_18x23.jpg)

Do we need a new approach?

Currently liquefaction potential is assessed on two scales: regionally based on surficial geologic unit or locally based on geotechnical sample data. Regional liquefaction potential maps fail to capture the variability of liquefaction potential on the local scale. On the other hand, collection of geotechnical data on the local scale is costly and only done for specific engineering projects and therefore not generally available for regional mapping. Therefore, the need for a new approach in liquefaction potential mapping is warranted.

Why Remote Sensing?

The advent of advanced remote sensing products from air and space borne sensors allow us to explore the land surface parameters (geology, moisture content, soil granularity, & temperature) at different spatial and temporal scales (remote sensor footprint) .

How can Machine Learning/Artificial Intelligence help?

Machine learning/artificial intelligence algorithm has the ability to simulate the learning capabilities of a human brain and make appropriate predictions for problems that involve intuitive judgments and a high degree of nonlinearity.

Methodology:

In this study, the liquefaction potential map was developed by a supervised classification using Support Vector Machine (SVM). The input features used are Landsat 7 ETM+ (Band 1-5,7), digital elevation model, ground water table, land cover classification, geology, water index, and normalized difference vegetation index (NDVI). The seven known classes of liquefaction probability for the supervised classification were obtained from Dupre and Tinsley, (1980). The developed map was validated using independent testing data that was not used for the supervised learning. A conceptual diagram of the methodology is shown in fig 2.

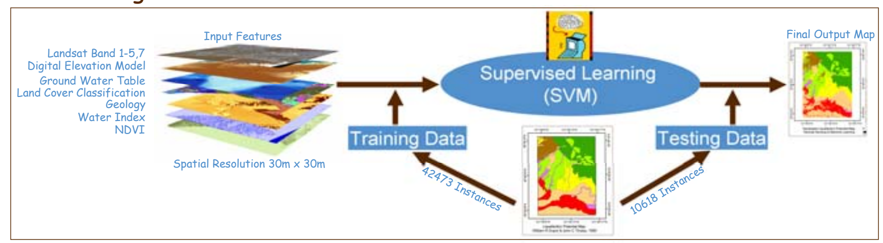

Figure 2: Conceptual diagram of the methodology used for liquefaction potential mapping.

Results:

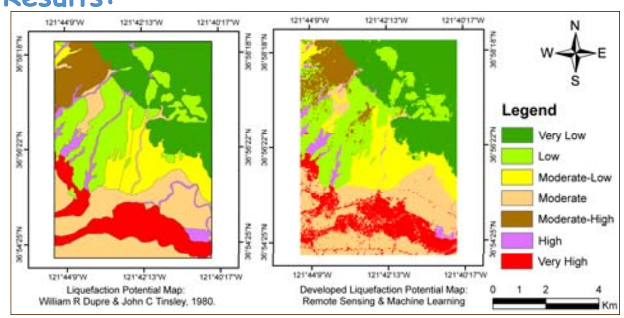

Figure 3: Comparison of the liquefaction potential map developed by Dupre & Tinsley, 1980 with the map developed in this study.

	Very Low	Low	Mod - Low	Mod	Mod - High	High	Very- High	Producers Accuracy
Very Low	2290	166	34	15	22	10	0	90.3
Low	92	1631	19	37	126	56	19	82.4
Moderate - Low	10	42	1144	115	8	9	1	86.1
Moderate	4	31	52	2000	3	113	275	80.7
Moderate -High	11	89	10	25	574	20	0	78.7
High	0	21	5	20	9	196	5	76.6
Very- High	0	5	2	229	0	6	1067	81.5
Users Accuracy	95.1	82.2	90.4	81.9	77.4	47.8	78.1	%

Table 1: Confusion matrix showing supervised classification accuracy of the developed map using an independent testing dataset.

- It is observed from fig 3 that the liquefaction potential map developed in this study compares well with the map developed by Dupre and Tinsley, (1980).
- Validation of the developed liquefaction potential map using independent testing data yields an overall classification accuracy of 83.4%.
- It is noted from Table 1 that both the users & the producers accuracy are greater than 75% for all classes with the exception of high where the users accuracy is 47.8% due to several moderate regions being mapped as high.

Conclusions and Future Work:

- The results show that the developed liquefaction potential map has an overall classification accuracy of 83.4%, indicating that the combination of remote sensing data and other relevant spatial data together with machine learning can be a promising approach for liquefaction potential mapping.
- The future work would concentrate on input feature optimization using genetic algorithm, variations in spatial & temporal classification accuracies, ensemble techniques (stacked generalization) and optimization of future data collection using active learning.

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