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A NEW APPROACH TO LIQUEFACTION POTENTIAL MAPPING USING SATELLITE REMOTE SENSING AND MACHINE LEARNING

Thomas Oommen
Department of Civil and Environmental Engineering, Tufts University, 113 Anderson Hall, Medford, MA 02155, USA. thomas.oommen@tufts.edu

Abstract

In order to help communities better plan and mitigate the effects of seismic hazards, it is important to use innovations in science and technology to improve our techniques for mapping the spatial extents of seismic hazards. Earthquake induced ground shaking in areas with saturated sandy soils pose a major threat to communities as a result of the soil liquefaction. Liquefaction is the process of changing a saturated cohesionless soil from a solid to liquid state due to increased pore pressure. Many major earthquakes, especially those in coastal regions, result in liquefaction related ground failures that can lead to infrastructure damage or slope stability issues. 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.

Today, the advent of advanced remote sensing products from air and space borne sensors allow us to explore the land surface parameters (geology, moisture content, temperature) at different spatial scales (remote sensor footprint). In this study, we explore the use of satellite based remote sensing data (Landsat 7 ETM+), together with digital elevation model, ground water table, land cover classification, geology, water index and normalized difference vegetation index (NDVI) to characterize the liquefaction potential of northern Monterey and southern Santa Cruz counties in California. A supervised classification of the data into seven classes based on the liquefaction potential map developed by Dupre and Tinsley 1980 was done using Support Vector Machine (SVM). SVM is a machine learning/artificial intelligence algorithm that has the ability to simulate the learning capabilities of a human brain and make appropriate predictions that involve intuitive judgments and a high degree of nonlinearity. Figure 1 shows a comparison of the developed liquefaction potential map using SVM to the map of Dupre and Tinsley 1980. It is observed that the spatial variability in liquefaction potential is well captured by the developed map. The accuracy of the developed liquefaction potential map was tested using independent testing data that was not used for the model development. The results show that the developed liquefaction potential map has an overall classification accuracy of 84%, 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. Further, Machine learning will be used to help understand the relative importance of the various parameters in identifying liquefaction hazard and to optimize future data collection efforts.

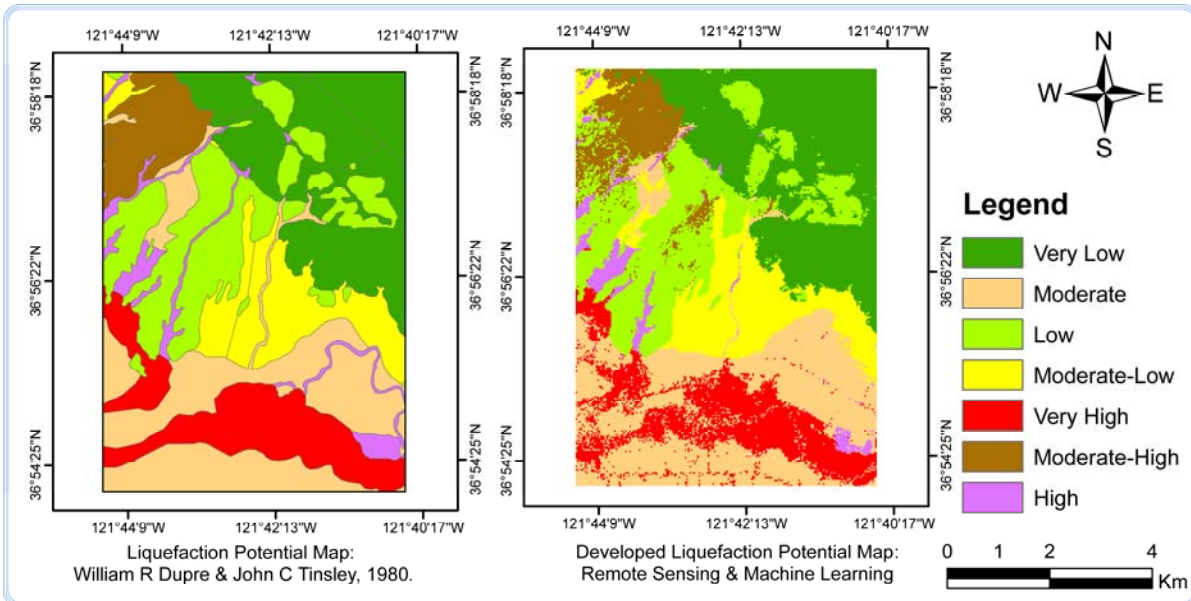

Figure 1: Comparison of the liquefaction potential map developed using remote sensing and machine learning to the map of Dupre and Tinsley (1980). It is observed that the spatial variability in liquefaction potential is well captured by the developed map.

Research Contribution to Geotechnical and Geoenvironmental Engineering Industry:

The liquefaction potential of a region is a major design consideration for a geotechnical engineer. The lack of spatial variability captured by the regional liquefaction potential maps based on surficial geologic units and the higher cost of collecting geotechnical data on the local scale, has led the recent research to include geotechnical boring data along with the surficial geology in characterizing the liquefaction potential. However, the challenge in this is deciding how to combine surficial geology information, which is on a regional scale and geotechnical boring information, which is on a site specific scale for the characterization.

Currently, the advancement in air and space borne remote sensing products allow us to explore the land surface parameters (geology, moisture content, temperature, other soil properties) at different spatial scales (0.6cm to 1km spatial resolution). This enables us to capture the variability in surficial soil properties in a much finer scale compared to the earlier regional surficial geology maps. This finer scale information can be further combined with the liquefaction potential obtained from sample data by supervised classification using machine learning/artificial intelligence algorithms. Thus this research provides a viable tool to geotechnical engineers in mapping liquefaction potential of a region combining surficial soil properties to sample data. This project also demonstrates the application of machine learning algorithms in geotechnical engineering. Moreover, machine learning is well suited to many problems in geotechnical engineering involving sparse data conditions and high degree of nonlinearity.

Reference:

Dupre, W.R., and Tinsley III, J.C., 1980, Maps showing geology and liquefaction potential of northern Monterey and southern Santa Cruz counties, California, U.S. Geological Survey, Map MF-1199.