Low-cost Sub-surface Landslide Monitoring and Associated Predictive Analytics

Thesis

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THESIS CERTIFICATE

This is to certify that the work contained in the thesis entitled, **"Low-cost Sub-surface Landslide Monitoring and Associated Predictive Analytics,"** being submitted by Mr. Ankush (Enrolment Number S18019), has been carried out under my supervision. In my opinion, the thesis has reached the standard fulfilling the requirement of regulation of the M.S. degree. The results embodied in this thesis have not been submitted elsewhere for the award of any degree or diploma.

Dr. Varun Dutt
25th March 2021

Declaration by the Research Scholar

I hereby declare that the entire work embodied in this thesis is the result of investigations carried out by me in the **School of Computing and Electrical Engineering**, Indian Institute of Technology Mandi, under the supervision of **Dr. Varun Dutt**, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made where the work described is based on the finding of other investigators.

Ankush
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25th March 2021

Declaration by the Research Advisor

I hereby certify that **Ankush** has carried out the entire work in this thesis under my supervision in the **School of Computing and Electrical Engineering,** Indian Institute of Technology Mandi. No part of it has been submitted elsewhere for any degree or diploma.

Dr. Varun Dutt
25th March 2021

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Abstract

Landslides are prevalent natural disasters in mountain regions. These disasters cause lots of deaths and infrastructure damages every year. Due to these damages and demises, it is crucial to monitor soil movements and warn people about imminent threats to give enough lead time to evacuate the sliding area. The technologies currently used for sub-surface monitoring of landslides are very costly, and these technologies do not upfront predict future soil movements and warn people. This research aims to detail the development, deployment, and evaluation of a new low-cost sub-surface landslide monitoring system. Specifically, we discuss the system's working and its indigenously built flexible casing that protects the system's electronics from subsurface water seepage. Other objectives of this research include predictive analytics about impending soil movements and alerts.

In the first experiment, we detail the construction of a sub-surface landslide monitoring system, its architecture, working, sensor placements, and packaging for monitoring weather parameters, soil properties, and soil movements. In the first experiment, we detail the reduction in the system's power consumption due to the redesign of the circuit and bootloader optimizations. The system's power reduction was compared to ATmega2560 (Mega)-based and ATmega328p (Uno)-based systems.

In the second experiment, predictive analytics of soil movements were performed on the data collected from a sub-surface system deployed in the field. Previous research has developed machine learning models to forecast soil movements. However, an evaluation of different models for soil movement predictions on sub-surface systems has been less explored. Also, little is known on how one could generate accurate alerts against landslides sufficiently ahead of time. Various machine learning models like Persistence, Auto-Regression (AR), Multi-Layer Perceptron (MLP), and Long-Short Term Memory (LSTM) were compared to forecast soil movements at a real-world landslide site. Specifically, we used data of soil movements collected by the landslide monitoring system installed at the Gharpa hill in Kamand, India, and trained persistence, AR, MLP, and LSTM models to predict downward soil movements. The root means squared error (RMSE) metric was used for model evaluation on a 70% training and 30% test data split. Results revealed that the AR and Persistence models gave the best and the second-best results, followed by the LSTM and MLP models, respectively.

In the third experiment, we developed and cross-validated a new ensemble gradient boosting algorithm for generating specific alerts about impending soil movements at a real-world landslide site. Data about soil movements were collected at 10-minute intervals via a sub-surface landslide monitoring system deployed at a real-world landslide site situated at the Gharpa hill, Mandi, India. A new ensemble support vector machine - extreme gradient boosting (SVM-XGBoost) algorithm was developed. An SVM algorithm's alert predictions were fed into an XGBoost classifier to predict the alert severity 10-minutes ahead of time. The performance of the SVM-XGBoost algorithm was compared to other algorithms including, Naïve Bayes (NB), decision trees (DTs), random forest (RF), SVMs, XGBoost, and different new XGBoost variants (NB-XGBoost, DT-XGBoost, and RF-XGBoost). Results revealed that the new SVM-XGBoost algorithm significantly outperformed the other algorithms in correctly predicting soil movement alerts 10-minutes ahead of time. We discuss the potential of developing a low-cost sub-surface landslide monitoring system and the utility of developing novel ensemble-based machine-learning algorithms for an alert generation against impending landslides in the real world.

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