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Ph.D. DISSERTATION DEFENSE

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Title: Towards the Automation of Mechanized Tunneling: Machine Learning Strategies for Enhancing Ground Prediction Models

Chairperson: **Chairman:** Prof. George Korfiatis, CEOE
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ABSTRACT

Mechanized tunneling is an effective and safe way to build tunnels, especially in urban areas with high population density. However, tunneling is subject to uncertainties, mainly due to unforeseen ground conditions, which can cause delays, cost overruns, and accidents. To help with decision-making and provide intelligent operational assistance, machine learning (ML) models have been used in several studies. These models use the data generated by Tunnel Boring Machines (TBMs) and aim to automate tunneling. Although these models have shown high performance during training, they still face challenges when used in actual construction projects. This research aims to address some of the limitations and research gaps hindering the application of ML models in construction projects. These challenges include a lack of generalization to other tunnel projects, data preprocessing and feature selection, noisy data, and a lack of model interpretability and confidence measures. The research begins with a thorough literature review to show the current state of ground prediction models and provide recommendations to bridge the gap between research and practice. Then, a systematic TBM feature selection strategy was developed to select the best input features for ground prediction models. This was achieved by training multiple ML ground prediction models, each with a different set of TBM input features, and observing their performance. Next, a data-driven framework called "confident learning" was adapted to identify incorrectly labeled data in tunneling datasets. This framework was also used to quantify the impact of label noise on the classification performance of ground prediction models. This is the first attempt to apply "learning with noisy labels" techniques in the context of tunneling applications. Finally, deep neural networks (deep ensembles) were used to quantify the predictive uncertainty of deep learning models for ground prediction and advance rate prediction. This is also a first attempt to quantify the uncertainty of ML/DL models in tunneling. In summary, this dissertation discusses the current applications of machine and deep learning in tunneling operations and introduces new techniques to improve the generalization performance of the tunneling operational models, provide a strategy to select the optimal set of TBM features for ground prediction models, identify mislabeled data, clean tunneling datasets, and quantify the predictive uncertainty of DL models. The end goal is to offer more interpretability to these models and enhance their performance