Supervised learning for back analysis of excavations in the observational method

Yingyan Jin

Abstract

In the past few decades, demand for construction in underground spaces has increased dramatically in urban areas with high population densities. However, the impact of the construction of underground structures on surrounding infrastructure raises concerns since movements caused by deep excavations might damage adjacent buildings. Unfortunately, the prediction of geotechnical behaviour is difficult due to uncertainties and lack of information of on the underground environment. Therefore, to ensure safety, engineers tend to choose very conservative designs that result in requiring unnecessary material and longer construction time. The observational method, which was proposed by Peck in 1969, and formalised in Eurocode 7 in 1987, provides a way to avoid such redundancy by modifying the design based on the knowledge gathered during construction. The review process within the observational method is recognised as back analysis.

Supervised learning can aid in this process, providing a systematic procedure to assess soil parameters based on monitoring data and prediction of the ground response. A probabilistic model is developed in this research to account for the uncertainties in the problem. Sequential Bayesian inference is used to update the soil parameters at each excavation stage when observations are available. The accuracy of the prediction for future stages improves at each

stage. Meanwhile, the uncertainty contained in the prediction decreases, and therefore the confidence on the corresponding design also increases. Moreover, the Bayesian method integrates subjective engineering experience and objective observations in a rational and quantitative way, which enables the model to update soil parameters even when the amount of data is very limited. It also allows the use of the knowledge learnt from comparable ground conditions, which is particularly useful in the absence of site-specific information on ground conditions.

Four probabilistic models are developed in this research. The first two incorporate empirical excavation design methods. These simple models are used to examine the practicality of the approach with several cases. The next two are coupled with a program called FREW, which is able to simulate the excavation process, still in a relatively simplistic way. The baseline model with simple assumptions on model error and another one is a more sophisticated model considering measurement error and spatial relationships among the observations. Their efficiency and accuracy are verified using a synthetic case and tested based on a case history from the London Crossrail project. In the end, the models are compared and their flexibility in different cases is discussed.