基於馬可夫隨機場的隨機模擬技術量化地層的不確定性

Li, Z., Wang, X., Wang, H., & Liang, R. Y. (2016). Quantifying stratigraphic uncertainties by stochastic simulation techniques based on Markov random field. *Engineering geology, 201*, 106-122.

報告者：王鼎崴
指導教授：董家鈞 老師
報告日期：2024/05/10

摘要

地層的不確定性指的是不同地層和岩性之間邊界的不確定性，並在地質工程中受到越來越多的關注。本文提出了一個基於馬爾可夫隨機場理論的有效隨機地質建模，基於現場調查資料，例如從地表觀察的土壤類型、鑽孔記錄以及從地球物理測試中得到的地層位態。所提出的建模方法能夠考慮地質結構的固有異質性和各向異性特徵，在這種方法中，引入了兩種建模方法(ICM、MCMC)來模擬地下地質結構，以滿足在不同地質結構類型的信心水準，並對這兩種建模方法進行了敏感性分析，以表示出網格密度和模型參數對模擬結果的影響。通過使用鑽孔數據的實例來說明量化地質結構不確定性的可行性。此外，詳細討論了兩種建模方法的適用性以及在不同模型參數下所提出的模型結果。最後，引入了貝葉斯推論，當額外或隨後的鑽孔信息可用時，對模型參數的後驗分布進行估計。提出可供工程應用的隨機地質建模技術。

關鍵字： 地質建模、土壤異質性、地層不確定性、不確定性量化、馬可夫隨機場

Quantifying stratigraphic uncertainties by stochastic simulation techniques based on Markov random field

Zhao Li [a], Xiangrong Wang [b], Hui Wang [c], Robert Y. Liang [a,*]

[a] Department of Civil Engineering, The University of Akron, Akron, OH 44325-3905, USA
[b] College of Engineering, Peking University, Beijing 100871, China
[c] Graduate School AICES, RWTH Aachen University, Schinkelstraße 2, Aachen, 52062, Germany

ARTICLE INFO

Article history:
Received 30 June 2015
Received in revised form 21 September 2015
Accepted 19 December 2015
Available online 28 December 2015

Keywords:
Geological modeling
Soil heterogeneity
Stratigraphic uncertainty
Uncertainty quantification
Markov random field

ABSTRACT

Stratigraphic (or lithological) uncertainty refers to the uncertainty of boundaries between different soil layers and lithological units, which has received increasing attention in geotechnical engineering. In this paper, an effective stochastic geological modeling framework is proposed based on Markov random field theory, which is conditional on site investigation data, such as observations of soil types from ground surface, borehole logs, and strata orientation from geophysical tests. The proposed modeling method is capable of accounting for the inherent heterogeneous and anisotropic characteristics of geological structure. In this method, two modeling approaches are introduced to simulate subsurface geological structures to accommodate different confidence levels on geological structure type (i.e., layered vs. others). The sensitivity analysis for two modeling approaches is conducted to reveal the influence of mesh density and the model parameter on the simulation results. Illustrative examples using borehole data are presented to elucidate the ability to quantify the geological structure uncertainty. Furthermore, the applicability of two modeling approaches and the behavior of the proposed model under different model parameters are discussed in detail. Finally, Bayesian inferential framework is introduced to allow for the estimation of the posterior distribution of model parameter, when additional or subsequent borehole information becomes available. Practical guidance of using the proposed stochastic geological modeling technique for engineering practice is given.