ENAC – School of Architecture, Civil and Environmental Engineering
SGC – Civil Engineering Section
LMS – Soil Mechanics Laboratory
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Pre-study and Master Thesis
Fall Semester 2023
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Development of a machine learning approach to facilitate the design of borehole heat exchangers

Supervisor: Professor Lyesse Laloui
Assistant : Dr. Elena Ravera

Motivation of the project

The design of vertical borehole heat exchangers (BHEs) requires the use of appropriate numerical modelling procedures. Thermal interaction effects between BHEs critically affect the performance of such heat exchangers, with the potential to cause detrimental energy performance and efficiency drops during the lifetime of such energy systems. The use of numerical modelling software for multi-physics systems is therefore necessary to consider all the physical processes governing the operation of BHEs, to accurately reproduce the thermal interactions between such heat exchangers, and to analyse in detail their energy performance and efficiency with due consideration of the fluid dynamics taking place within the BHE tubes. The design of these systems is a complex and iterative process with simulations usually having to be done over periods of 50 years with long simulation times that in practice result in high costs. This project will investigate the use of machine learning techniques to optimize the design of these energy systems. The approach would be used alongside numerical simulation to speed up the design optimisation process.

Keywords

Geothermal energy, machine learning, borehole heat exchangers, Finite element analyses (COMSOL Multiphysics), Data-driven predictions.

References

Bourhis, P., Cousin, B., Loria, A. F. R., & Laloui, L. (2021). Machine learning enhancement of thermal response tests for geothermal potential evaluations at site and regional scales. Geothermics, 95, 102132.

Makasis, N., Narsilio, G. A., & Bidarmaghz, A. (2018). A machine learning approach to energy pile design. Computers and Geotechnics, 97, 189-203.

Zhuang, Z., Ben, X., Yan, R., Pang, J., & Li, Y. (2017). Accurately predicting heat transfer performance of ground heat exchanger for ground-coupled heat pump systems using data mining methods. Neural Computing and Applications, 28(12), 3993-4010.

Zhuang, Z., Zhai, X., Ben, X., Wang, B., & Yuan, D. (2021). Accurately predicting heat transfer performance of ground-coupled heat pump system using improved autoregressive model. PeerJ Computer Science, 7.

Goal of the project

By the end of the project, the student is expected to be able to predict heat transfer performance of BHEs using machine learning techniques.

Tasks and work to carry out

- Literature review
- Understanding of the current formulation of numerical models for BHEs
- Identification and development of machine learning technique for BHEs
- Representation of the results in a consistent and effective manner
- Compose a project report in written form
- Presenting a project orally

Deliverables

- Report

The student will have to prepare a technical report containing the introduction and motivation for the project, the description of the accomplished work and related results as well as conclusions. The technical report will have to be prepared in an electronic format and send to the supervisor and the responsible of the project by the end of the semester.

- Final Presentation

The student will have to present his work during a presentation at the end of the semester. The day and the place of the presentation will be communicated to the student.

Planning

- Meetings and presentations

A weekly meeting (on Friday pm) with the assistant is suggested to discuss the progress of the project. One meeting per month will be organised with Prof. Laloui (dates will be communicated to the student). During the meetings with the assistant, the student will have to present (i) the progress of the work, (ii) possible questions and remarks and (iii) a summary of the next steps for the project. During these meetings, the supervisors may vary the foreseen goals of the project, if necessary. The student will have to prepare all the possible questions before the meeting in written form and a summary of each meeting for the next fixed meeting.

- Report

The report will be written in English. Graphs will be built with the Grapher software, Matlab, or with the aid of Microsoft Excel. Particular attention will be given to the writing up of the report. In the document, the student will have to clearly introduce the topic, to highlight the hypotheses made, to present the considered methodology, to discuss the obtained results and to draw the related conclusions.

- **Electronic files**

At the end of the project, the student will have to send to the supervisors a folder containing a clear classification of all the electronic files developed during the project, including those related to the reports, obtained data, presentations, poster and graphs.

Grading

The final grade will be assigned considering the following proportions of contribution:

- Technical report 70%
- Oral presentation 30%

The evaluation will also consider the work methodology, discipline and resourcefulness of the student.

General rules of the project

The schedule of the project is defined by the EPFL Academic Calendar:
https://memento.epfl.ch/academic-calendar/?period=180

The student signature on the submitted report certifies that the work is original and developed by him/herself. This work is property of the EPFL and cannot be disseminated without the approval of the considered Institution.

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