Haute école d'ingénierie et d'architecture Fribourg
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COMPUTER SCIENCE

OptiSoil

Artificial Intelligence applied to the process of excavation for buildings construction

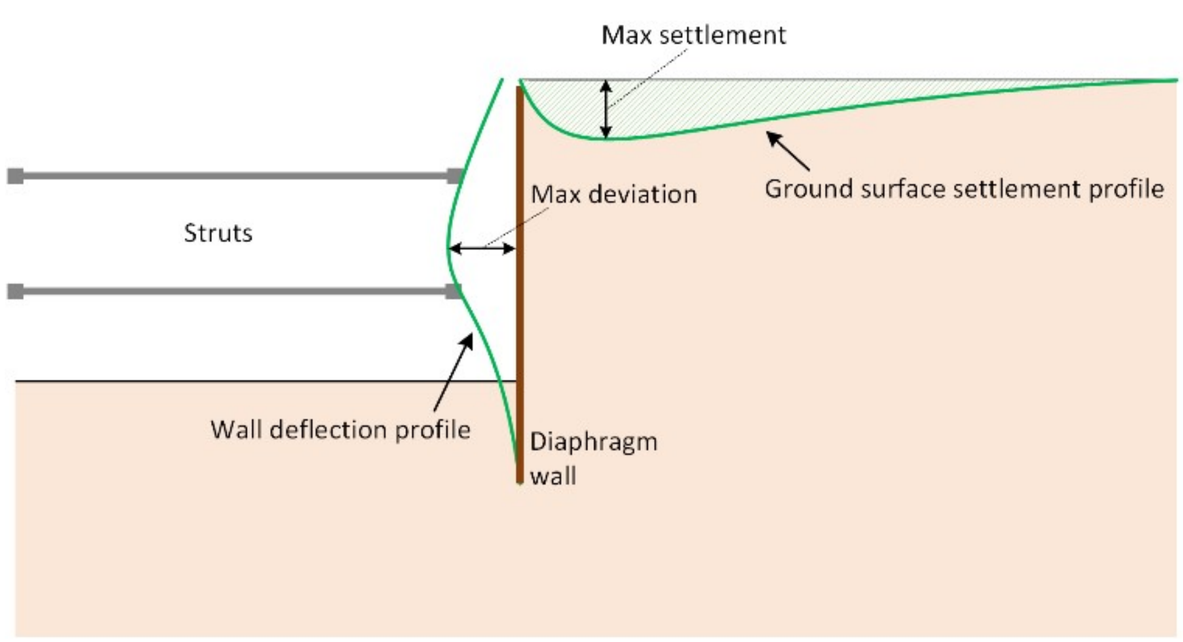
CONTEXT

In several technical domains, such as civil engineering, numerical simulation programs based on finite elements help simulate the behaviour of the studied components. This project studies the process of excavations for building construction. In this field, the ZSWalls software is known to be able to predict accurately internal forces in the support system (concrete or steel wall, anchors, …) and associated displacements, given the geometry of the excavation, the stratigraphy, the water level, and the support system itself. We take advantage of this software to build a synthetic database composed of thousands of excavations, and then use machine learning to predict the results of a new case, which is much faster than a new numerical simulation.

Typical braced excavation, Geneva, 3 levels of struts

OBJECTIVES

- Create and train models in order to predict collapse (classification), settlement, deviation and bending moment (regression)
- Implement an application which uses these models in order to find the best configuration for a given excavation (optimization)



Schematic picture of the excavation with associated displacements
The bending moment (not represented here) is an internal force inside the wall

INNOVATIONS

- Reproduction of numerical simulation results by a neural network
- Data-sets generation through numerical simulation, opposed to the traditional method of data collection. **Any field with numerical simulation at disposal could use this method**
- Transformation of numerical data to CNN-compatible format (image-like data)

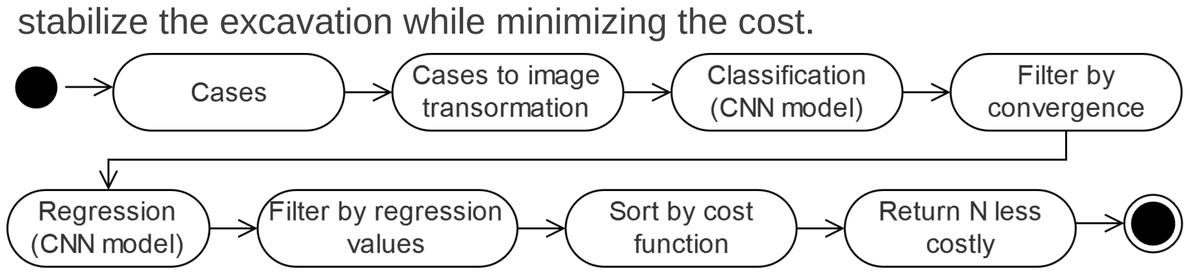
RESULTS: CONVOLUTIONAL NEURAL NETWORK AND APPLICATION

The generated database is used to train a convolutional neural network (CNN) which computes the behavior of the excavation (internal forces and displacements), and classify whether or not the excavation will hold. A particular data processing step is necessary to transform physical values to convolutional-network-compatible input. Classification gives about 6% false-negative for no false-positive.

	Settlement	Deviation	Moment max	Moment min
Metric 4 [%]	4.26	7.24	5.93	4.49

Results of the models
The "Metric 4" is a customized metric, similar to the relative error, modified to avoid amplifying errors close to 0.

An application is developed which generate synthetic cases and uses the trained models to predict the behavior of a new case. An optimization process allows selecting cases that are good candidates to stabilize the excavation while minimizing the cost.



Optimisation process in the application

The application gives good results close to production-grade values for cases which are similar to those present in the database (up to three different soils and three support levels)
- OptiSoil application: 20'000 cases evaluated in about 15 seconds
- Numerical simulation: about 90 seconds per case

CHALLENGES

The project stil faces two main challenges:
- **Database:** database quality is absolutely crucial for the model to work properly. In the future, a new synthetic database will be created, in order to correct the detected flaws, and cover most real-life cases
- **Model training:** help the machine learning algorithm to think like an engineer

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