Machine learning-based generative design and verification of construction pits

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Background and Problem statement

For almost every construction of building or bridge a construction pit needs to be designed. As parts of the project may change in size and location, the surrounding soil will not stay the same. Hence the design of the construction pit must be adjusted.
A broad data base composed of existing design choices and results from the design software, would enable the training of a machine learning algorithm from which suggestions can be made. This would allow for an efficient and fast design proposition including a rough static verification of the construction pit. The goal of this Master's Thesis is to train and score a machine learning algorithm to suggest an initial design of construction pits for a proposed set of input parameters from the user.

Machine Learning

Machine learning is part of the area artificial intelligence.
Supervised learning is like having a teacher. You have examples with the input parameter and the correspondent output. This data set is labelled and is used for training and testing the algorithm.

Unsupervised learning is to find a structure in unlabelled data → Clustering

In Reinforcement Learning a desirable output is known. Comparing with the output it learns from errors.

Overview

As shown in Figure 1 a reasonable range for input parameter has to be defined. After that a Solver (= Generator + Evaluator) can be used which generates and evaluates solutions for each construction pit, using finite element method. From its solution the following output parameters had been selected: deformation, bending moment distribution, wall length and utilization ratio. The data base was used for artificial intelligence / machine learning and for fitting the function which predicts the desired output for a given input.
That is how a recommendation for a retaining system is giving. An additional option for the follow up is to include objectives into the data base, such as material costs, installation space and construction time. With this objectives the model is more interesting for engineering office.

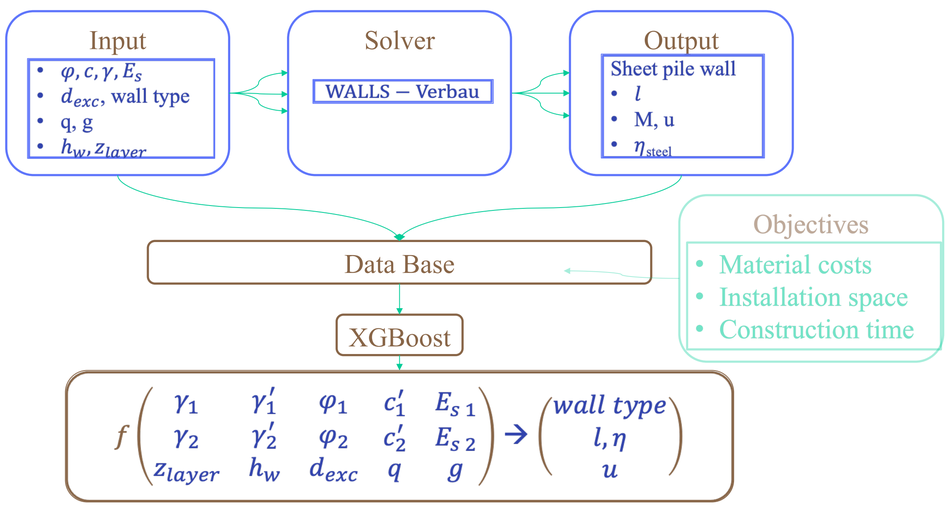

Figure 1: Aim of Artificial Intelligence application in construction pits

Results

In Figure 2 the results of XGBoost fitting wall length are presented. With a sample size of 1000 calculations per sheet pile three XGBoost models were each trained one for predicting deformations, the second for the maximum bending moment and the last one for the wall length.
It shows a high correlation with the identity (the green line) $R^2 = 1$ and a CoV = 0.198

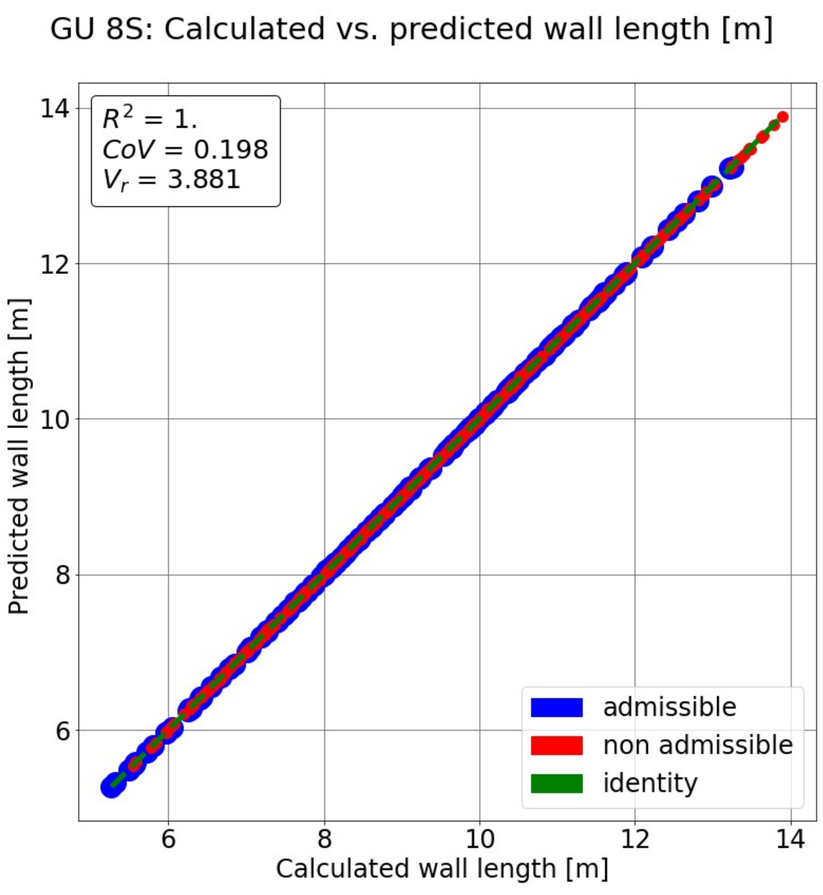

Figure 3: Results of XGBoost fitting wall length

Graphical user interface (GUI)

The graphical user interface is shown in Figure 3. At the top the user may enter the input parameters. On the right side of the image in the window the prediction are presented and a recommendation for an initial design is given.

For coding the GUI toolkit: tkinter package was used. "Tk interface" is the standard Python interface to the Tk GUI toolkit.

The Python Pillow (aka PIL) package for displaying an image-based message was used.

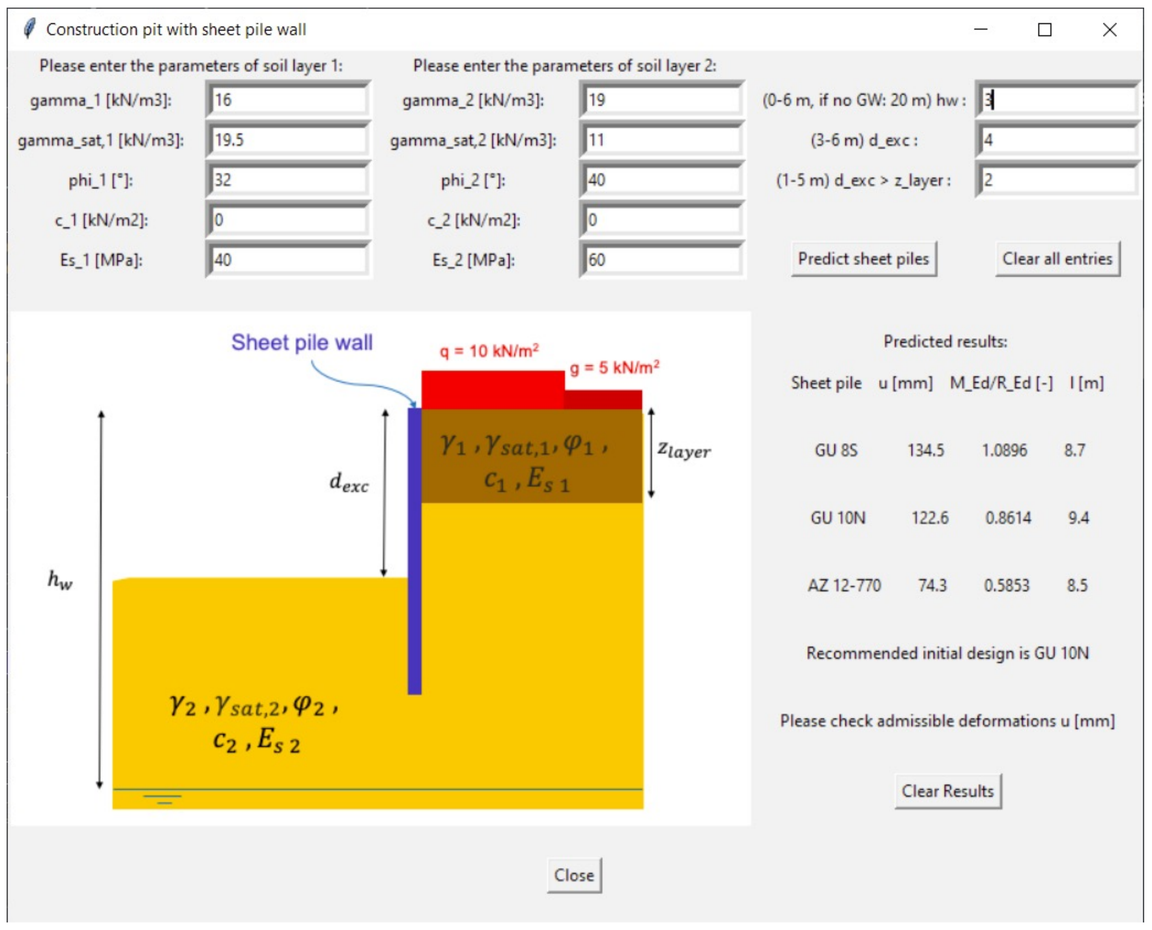

Figure 3: Graphical user interface (GUI)

Conclusion

Working with a machine learning application in civil engineering was very interesting and challenging to explore. The cooperation and support from Fides GmbH was important. For the proof of concept of the whole aim, more simplification for first steps were needed.
Goal achieve with eager learning: The training took almost a week but the prediction takes less than a second.

→ With recommendation for initial design Engineers may save time in future ☺

Outlook

This thesis is only considering the sheet pile wall as retaining system. To gain value in application for engineers, the data base requires to be completed with other different retaining systems as soldier pile wall, bored pile wall and MIP wall. For more utility to complement this data with objectives as material cost, installation space and installation time. To get a more realistic utility also deeper construction pits should be considered and therefore anchored retaining system.

Applying machine learning and generative design in this specific geotechnic field is innovative promising and there is still a lot to do.