Application of geometric and geologic information for optimization in construction projects

Focusing on parametric design and machine learning in Engineering Geology

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Outline

- Introduction to parametric design in Rhino and Grasshopper
- Parametric model of rock support in rock slope
- Parametric model of rock support in tunnelling
- Parametric model for drilling geometry in rock grouting
- Machine learning in engineering geology – example from rockmass classification in advance
Parametric 3D modelling
Using Rhino and Grasshopper
The what?

A combination of **CAD software** and **programming interface** to create 3D geometries.

**Rhino** is used to visualize results (CAD)

**Grasshopper** is used to create the geometry, and much more...
The what?

- Geometries are **parametric** – we can change the parameters to modify the model seamlessly.

- Geometries are **computational** – we apply math to create the design.

- Geometries can be **generative** – we can iterate the process based on goals to obtain the best solution.
The how?

- We use **Grasshopper** – a visual programming tool.
- It’s like scripting – but simply more **intuitive**.
- We can create **complex** geometries in 3D with little effort – fast and efficient.
- On this geometry we can perform **evaluations** and **analysis**.
- We can then **communicate** our design and results using BIM and VR, or export to drawings.
- Suitable for development of **discipline models** in rock support, rock grouting and geotechnical constructions.
Parametric model of rock support in rock slope

Example from E18 Rugvedt-Dørstad
Parametric model of rock support in rock slope
Parametric model of rock bolting in tunnel
Parametric model of drilling geometry for rock grouting
Old design system – one system for the whole tunnel
Goals with scripts

1. Design grouting geometry in a parametric 3D way «on the fly»
   - New design process: tailormade grouting geometry for each unique rock face (use data from engineering geology mapping on face + automated mapping with plane detect etc, MWD) >>> reduce drilling to achieve the leakage requirement
   - Reduce quantities in grouting (drilling time, grouting time, grouting materials).
   - Ensure optimal covering of the tunnel profile

2. Discipline model for grouting in a parametric and quick way

3. Tool for estimation of quantities for grouting
Machine learning in applied geosciences
Emerald - construction of bedrock topography

Geotechnical drillings:
- Expensive site investigation
- Time consuming
- Accurate, but very local

Geophysics:
- Less expensive
- Very fast
- Covers large volume
- Greater uncertainty
Monitoring system of the Baijiabao landslide
LSTM model for prediction of displacement
Rockmass classification from MWD-data

Holmestrandstunnelen:
- 4 km of MWD-data – blasting holes
- Mapped Q-value and rockmass class

Goal: Predict rockmass class in front of the face, in order to plan in advance:
- Wider profile for heavy rock support
- Spiling bolts
- Other operational planning
Measure while drilling (MWD)

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Photos and figures: NFF Publication 28
Geology and rockmass classes
Modelling process

Built on experience from:
- Eldert et. al (2019), Application of MWD technology to predict rock mass quality and rock support for tunneling
- Hayashi et. al (2019), Prediction of forward tunnel face score of rock mass classification for stability by applying machine learning to drilling data.

Combined 290 sections of blasting rounds
Preprocess, clean and scale data
Downscale 150-170 blast holes in each section to 3 summary-parameter (mean, median, variance) for each MWD-parameter, in total 18 parameters + blasting length and mapped rockmass-class from last section
Challenge – downscaling (dimension reduction)
We use KERAS running on top of TensorFlow in Python to perform a supervised non-linear regression analysis. The Artificial Neural Network (ANN) is a Multilayer Perceptron (MLP) model and consists of three layers with a width of 250 neurons each. We have 20 Input parameters, 1 Output per depth, and as the output, we use the Rockmass class.
Results

75/25 Train and Testset (unseen data for the model)

Algorithms tested out:
- Logistic regression: 59%
- KNN: 48%
- Random Forest: 72%
- Gradient Boosting: 81%

83+/- 8% accuracy on test set with neural network

Further development:
- Increase accuracy close to 100% based on clustering and principal component analysis (PCA) – before neural network.
- Build a more general model based on data from many tunnel projects. Need more data 😊
- Predict from drilling for grouting 10-15-20 m in advance
Closing the circle - 3D/BIM in parametric design and tools for machine learning

Modules for machine learning in Grasshopper
#påsikkergrunn