INTEGRATING MULTIPLE GEOTECHNICAL DATA TYPES WITH MACHINE LEARNING TO CONSTRUCT HIGH-RESOLUTION 3D GEOLOGICAL MODELS

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The Northern Lek River dike protects a large and densely populated area of the Netherlands, including the cities Utrecht and Amsterdam.

Water Authority Hoogheemraadschap De Stichtse Rijnlanden (HDSR) maintains the dike and launched the project ‘Sterke Lekdijk’ for large scale reinforcements.

The strength and stability of the dike depends
• on its design
• the composition of the subsurface
DIKE FAILURE MECHANISMS RELATED TO SUBSURFACE CONDITIONS

Detailed knowledge of the subsurface is essential!
Geological Survey of The Netherlands develops and maintains GeoTOP model, based on ~ 580,000 boreholes.
GEOTOP WORKFLOW

- Lithostratigraphical interpretation of borehole logs
- 2D interpolation of stratigraphical surfaces
- 3D interpolation of lithological class within each stratigraphical unit

Layer-based model

Voxel model

Stochastic simulation techniques allow quantification of uncertainty
GEOTOP 3D VOXEL MODEL

~2/3 coverage of Dutch subsurface
Resolution 100 x 100 x 0.5 m
Each voxel contains information on:
  - Geological unit
  - Lithological class (sand, clay, peat)
  - Lithological class probability

15 km
50 m below surface level
COMPLEX HOLOCENE GEOLOGY

- Lek river dike built on complex Holocene geology
- Regional GeoTOP model provides 100 m horizontal resolution
- Dike reinforcement projects require more detailed subsurface model
AVAILABLE BOREHOLE AND CONE PENETRATION TESTS
CONE PENETRATION TEST (CPT)
Lithological classification adapted from Robertson (2010) classification chart to identify GeoTOP lithological classes

- Classification chart designed for geotechnical classes
- Lithological classes clayey sand and peat hard to identify
- Needs tuning based on local geology
FROM CONE PENETRATION TEST TO LITHOLOGY: ARTIFICIAL NEURAL NETWORK

Network design
• 2 Dense hidden layers
• Classify CPT parameters to lithological classes

Train with local data
• 231 pairs of closely spaced boreholes and CPT’s were available
CROSS VALIDATION RESULTS

Based on Robertson (2010)

Artificial neural network

Single CPT – borhole pair

Confusion matrix
HIGH-RESOLUTION SUBSURFACE MODELLING

- Machine Learning techniques allow harmonization of multiple data types.
- Using cone penetration tests together with borehole information greatly increased data density, justifying very detailed modelling.
- High-resolution subsurface models facilitate new applications that need detailed information about local geology.

‘normal’ GeoTOP (regional model)

Voxel size 100 x 100 x 0.5 m

High resolution GeoTOP (local model)

Voxel size 25 x 25 x 0.25 m
COMMUNICATION & CONCLUSIONS

- Machine learning can help getting more out of available data
- More data enables detailed models
  - more specific for experts
  - brings geology closer to non-experts

Combining information above & below the surface in Digital Twin environment