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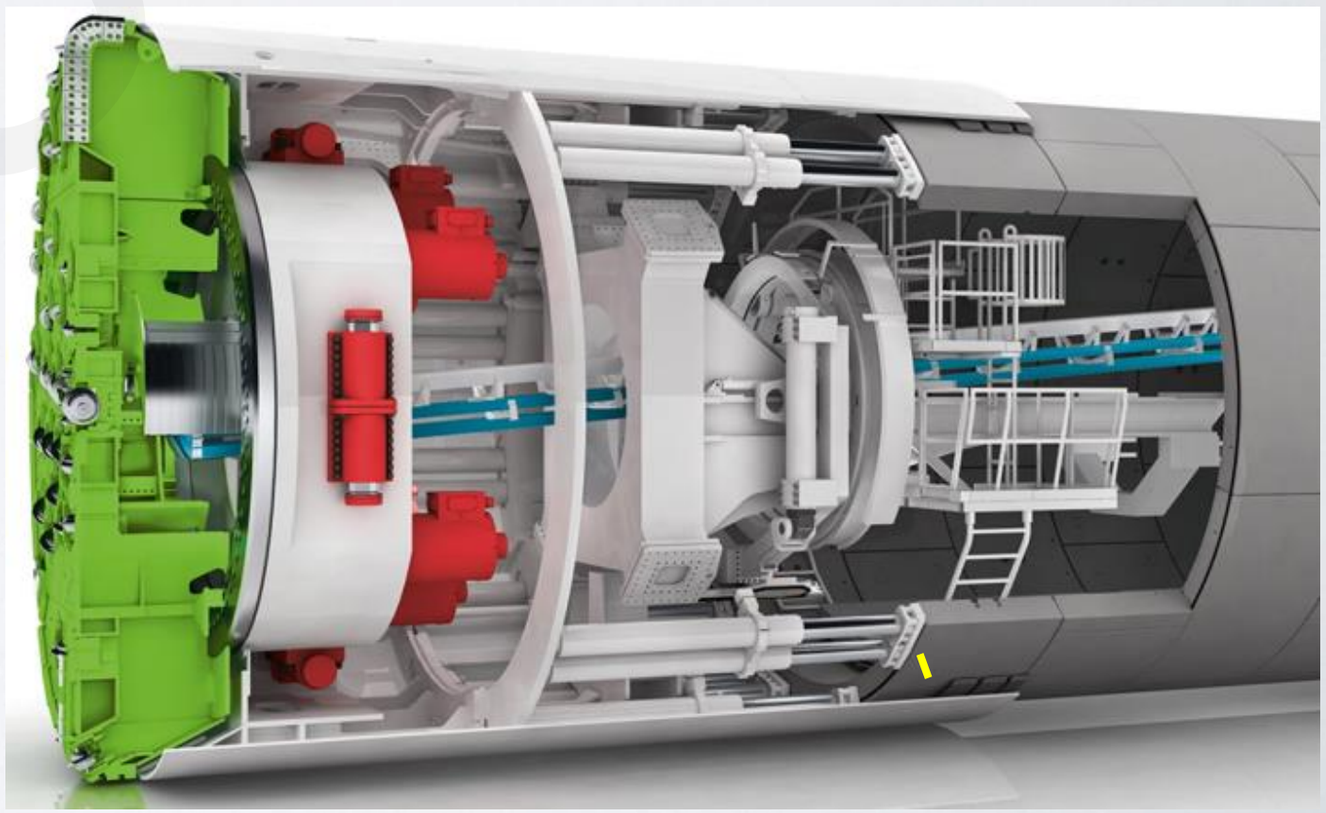
Intelligent segment typesetting in shield tunneling based on artificial neural networks and transfer learning

Key words:
Shield tunneling,
Segment typesetting,
Assembly points,
Artificial neural network (ANN),
Bayesian optimization,
Transfer learning



Background

During shield tunneling, the shield machine advances while installing precast segments. However, segment typesetting is highly constrained and still relies on the operator's discretion, easily leading to serious accidents.

Many constraints

- Thrust cylinder stroke differences
- Shield tail gaps
- Principle of staggered-joint assembly
- Many types of segments

Operator's discretion

Serious accidents

- Segment breakage
- Misalignment of axis
- Shield machine control loss

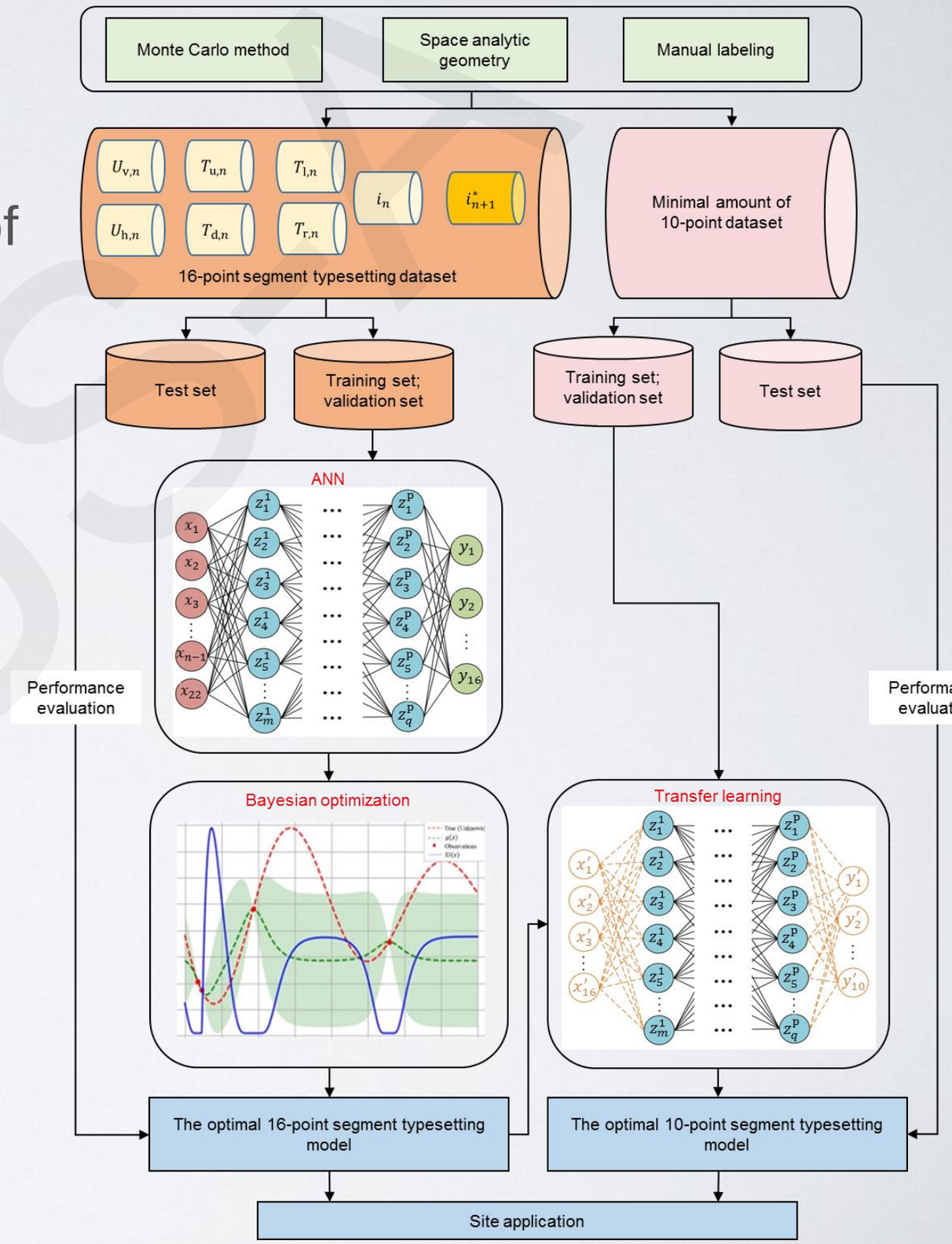
Accurate, rapid, and intelligent segment typesetting in shield tunneling is an urgent issue that must be addressed.

Limitations of Data-Driven Methods

- Requirement for Extensive Data
  - Data-driven modeling necessitates large amounts of historical data
- Challenges in Data Acquisition from the Field
  - Confidentiality of Site Data
  - Imbalance in Field Data
  - Limited Volume of Field Data

Proposed method

- Generate simulation data: Large dataset of 16-point segment typesetting and a smaller dataset of 10-point data
- Train ANN model for 16-point segment typesetting
- Optimize hyperparameters using Bayesian optimization
- Train 10-point segment typesetting model through transfer learning
- Implement site application



Highlight and Conclusion

Highlight:

- Created a dataset for segment typesetting incorporating constraints like thrust cylinder stroke differences, tail gaps, and assembly principles.
- Developed a high-accuracy intelligent typesetting model for 16-point segments using ANN and Bayesian optimization.
- Introduced a transfer learning technique that generalized the model to other segment types, such as 10-point segments, addressing modeling challenges with limited data.

Conclusion:

- The ANN model outperformed KNN, SVM, DT, and some existing engineering methods in 16-point segment typesetting accuracy.
- The 10-point model, built with transfer learning, significantly surpassed models trained on small datasets, confirming the effectiveness of the generalization technique.
- In field validation, the 16-point and 10-point models achieved accuracies of 93.75% and 91.43%, respectively, exceeding manual decision-making by 15.62% and 34.29%, indicating strong potential for replacing manual processes.