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SIMULATION AND MONITORING-BASED STEERING FOR MECHANIZED TUNNELING USING PROJECT DATA OF WEHRHAHN-LINIE

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A strategy for a simulation and monitoring based steering of tunnel boring machines during the construction process is proposed and demonstrated by means of project data from a tunneling project (Wehrhahn-Linie (WHL) Düsseldorf, Germany). The computational concept consists of a model update based upon monitoring data and of the determination of optimal tunnel machine-related parameters to minimize tunneling-induced settlements. Since the steering support during construction is required in real time, a neural network model is used as a meta model for this purpose, substituting a computationally demanding 3D finite element simulation model [4]. The Tunneling Product Model (TPM) [1], containing the project data of WHL, is used to define a set of simulations for the meta model. The meta model of WHL is used in conjunction with Particle Swarm Optimization (PSO) [2] as a global optimization algorithm for back analysis of soil parameters based on monitoring data and, if the predicted surface settlements exceed allowed values, for optimization of machine parameters in order to reduce settlements to the magnitude of tolerated values.

In order to manage the huge amount of time dependent, dispersed and heterogenous WHL project data, a holistic 4D information model for mechanized tunneling has been proposed [1]. All relevant design and construction information has been collected, classified, structured and linked within the proposed 4D TPM to support a unified access. This model is designed using the concept of Building Information Modeling (BIM) and contains four essential sub-models, namely the ground data model, the tunnel machine model, the tunnel lining model, and the built environment model. These models are inherently linked and provide the basis to automatically derive numerical simulation models [6].

The meta model for the WHL tunnel project is based on a large number of numerical simulations with different geometrical, material and machine-operational parameters ("numerical experiment"). Information about the geometry of the tunnel, geological formations, upper and lower limits of material and machine parameters are provided from the TPM. An advanced FE simulation model for mechanized tunneling [3] is used as the basis for performing the numerical experiment of the mechanized tunneling process for the WHL range of data. To minimize the required manual intervention, the numerical experiment is fully automated (from the generation of the models, pre- and post-processing of simulation data to creating and validating the meta model) [4]. The data set obtained from the numerical experiment is used to create the meta model. A neural network model is trained using a back-propagation algorithm [5], with the architecture and the network-related parameters being optimized using a global optimization approach.

The meta model for WHL is first evaluated with field measurements of tunneling-induced settlements in prior sections of the tunneling process with respect to the current machine position. However, if the meta model predictions mismatch in situ observations, back analysis is performed to identify uncertain soil parameters. With the updated meta model it is possible to obtain reliable predictions of maximum induced settlements for upcoming positions of the tunnel machine. If minimization of settlements is required, PSO is used to optimize support and grouting pressures of the machine. The updated meta model is used for evaluation of the objective function, which makes this analysis fast and robust, and enables real-time steering of the mechanized tunneling process.

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