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Framework for the Development of a Mineral Resource Digital Twin

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Abstract

A mineral resource is a concentration of solid material of economic interest in or on the Earth's crust with reasonable prospects for eventual economic extraction. Mineral resource models are commonly generated using specialised software applications, based mostly on information from exploration programmes and mine production. Updating of mineral resource models with new information involves repeating most, if not all, of the modelling stages, even if the new information only affects part of the model. Mineral resources represent static entities (deposits) that change only due to human intervention (mining). Digital twins are virtual representations of entities that span their lifecycle, are updated from real-time data, and use various simulation, machine learning and reasoning algorithms to help decision-making. So, one could question the need for the development of a digital twin to represent a mineral resource. However, our perception of a mineral resource is dynamic and changes through time during various stages of mineral exploration and later during mining with the inflow of new information from various sources. The purpose of this study is to establish a framework for the development of a digital twin that represents a mineral resource, enabling effortless and dynamic integration of new information and updating of the mineral resource model.

Background and Objectives

A few researchers have worked recently on finding ways to automate the process of generating a mineral resource / reserve model. Benndorf *et al.* (2016) introduced the concept of an integrated framework for real-time reserve management incorporating sensor-based material characterisation, geostatistical modelling under uncertainty, modern data assimilation methods for a sequential model updating and mining system simulation and optimisation. Wambeke *et al.* (2018) performed a pilot study to demonstrate a new process for updating block estimates using actual mill performance data. Hodjkinson *et al.* (2020 provided an overview of digital twin concepts and how these can be considered in the case of geological models. Servin *et al.* (2021) provide an example of a system for tracking material from mine to mill using digital twin technology. Kumar and Dimitrakopoulos (2022) describe a system for updating geostatistically simulated models of mineral deposits in real-time with new information using reinforcement learning. Our study aims at developing a digital twin of a mineral resource by breaking down the mineral resource modelling process to all applicable steps, identifying, formalising, and organising information from the available sources, identifying and configuring all the required model entities (grids, triangulations, block models, etc), and, selecting and configuring the necessary data processing and modelling algorithms.

Methodology

The Workflow Editor (WE) from Maptek was chosen as a software platform to develop and test prototype digital twins of mineral resources. WE allows users to design, save and run automated software procedures called *workflows* (Maptek, 2022). They consist of a series of *components* connected by arrows indicating the sequence of execution and the flow of data. Workflows may be fully automated or may consist of a combination of manual and automated steps, alternate paths of execution based on user input (decision-making ability), and customised behaviour. Workflow components generate data called *attributes* that are transported to other components via *connections*. WE provides a number of components, ideal for the development of mineral resource digital twins:

- **Data Editor:** provides a snapshot of the current state of the workflow's data. It allows inspection, adding or removing attributes, items, and files and changing of their value.
- **Data Filter**: used to remove attributes or items from input data.
- **Data Trigger**: used to detect an event within the Workbench or on the file system to trigger actions in a workflow.
- **Decision**: used to alter the flow of execution depending on user input.
- **End of Loop**: used to mark the end of looping over several components. When there are loops defined that span multiple components, it returns control to the top of the loop for the next iteration item.
- **Timer**: delays the execution of the previous component. The timer starts when the component is activated, and the component is completed when the time has expired. In the example below, a Python expression is executed on each value in a list. The timer is added so that the user can view the results at each step.
- **Waypoints**: used to make diagrams clearer to navigate for the user and provide control over the flow of data.

Figure 1 shows a simplified version of a workflow used to generate a mineral resource model using three basic sources of information (drilling, topography, and geology). The workflow reacts to any changes to the source data and repeats the process(es) that is affected by the changes – in this case a change in the drillhole data – plus all downstream processes. Processes unaffected by the changes stay inactive and any downstream processes run using the results of unaffected higher processes derived earlier.

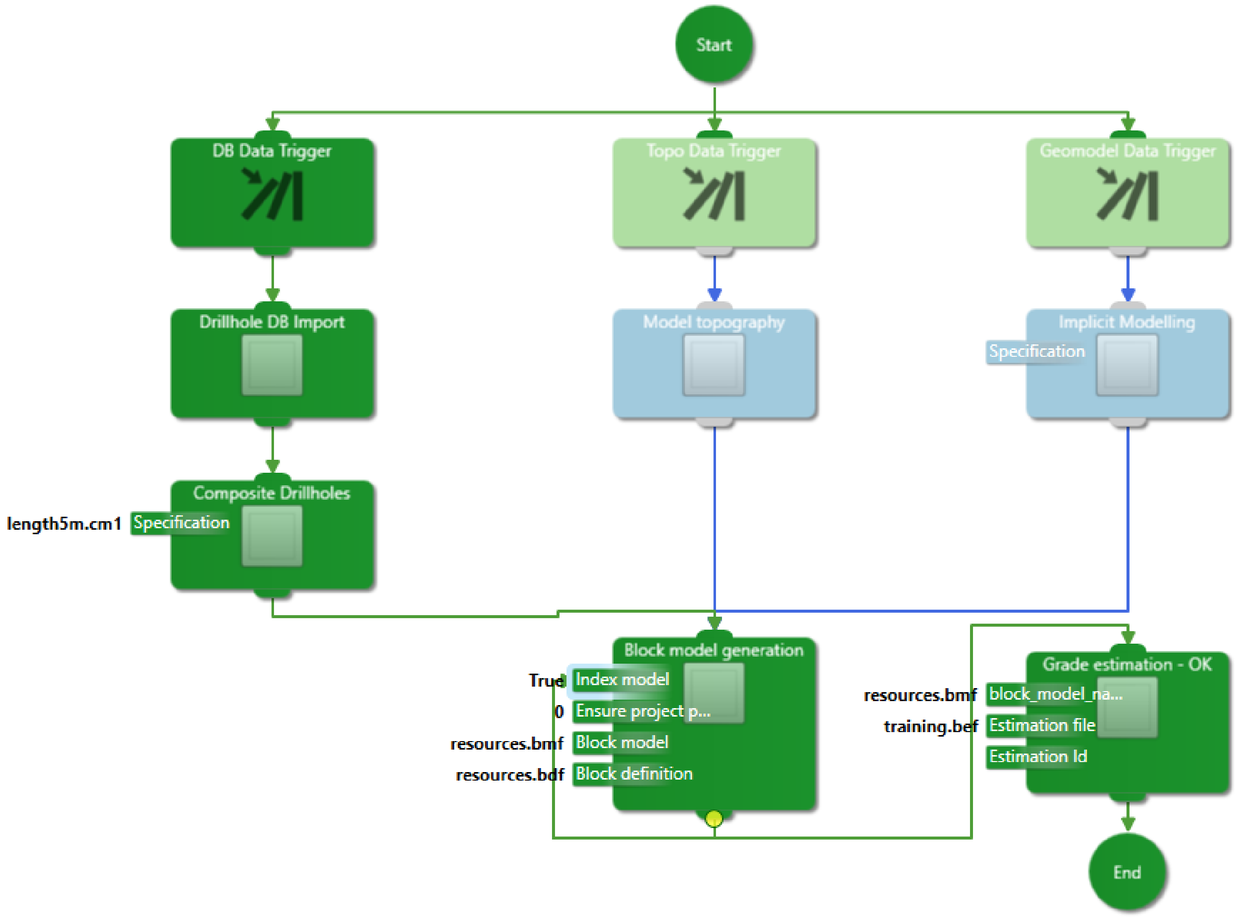

Figure 1. Simple workflow used to generate and estimate a resource block model from drillhole, geological and topographical data, after an update triggered by a change in drillhole data.

Conclusions

Representing the process of modelling a mineral resource as a workflow in WE allowed the utilisation of certain components that can make modelling dynamic, responding to changes in the input data provided at any stage. The flow of data as attributes of the workflow, allows modelling processes to be reconfigured according to changes to the input data. Overall, with the system discussed in this paper, it is possible to develop digital twins of mineral resources that dynamically react to data changes, not only by simply repeating some or all the modelling processes, but also by adjusting the processes themselves to suit the new data.

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References

Benndorf, J., W. N. Buxton, M.W.N., 2016. Sensor-based real-time resource model reconciliation for improved mine production control – a conceptual framework, Mining Technology, 125:1, 54-64, DOI: 10.1080/14749009.2015.1107342.

Hodjkinson, J.H., Elmouttie, M., 2020. Cousins, Siblings and Twins: A Review of the Geological Model's Place in the Digital Mine. Resources 2020, 9, 24; DOI:10.3390/resources9030024.

Kumar, A., Dimitrakopoulos, R., 2022. Updating geostatistically simulated models of mineral deposits in real-time with incoming new information using actor-critic reinforcement learning. Computers & Geosciences 158 (2022) 104962, DOI: 10.1016/j.cageo.2021.104962.

Maptek, 2022. Workflow Editor Help (Offline).

Servin, M., Vesterlund, F., Wallin, E., 2021. Digital Twins with Distributed Particle Simulation for Mine-to-Mill Material Tracking. Minerals 2021, 11, 524. DOI: 10.3390/min11050524.

Wambeke, T., Elder, D., Miller, A., Benndorf, J., Peattie, R., 2018. Realtime reconciliation of a geometallurgical model based on ball mill performance measurements – a pilot study at the Tropicana gold mine. Mining Technology, 127:3, 115-130, DOI: 10.1080/25726668.2018.1436957.