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Simulation Tool to Analyze the Productivity and Energy Consumption of Electric Mining Vehicles

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Simulation tool to analyze the productivity and energy consumption of electric mining vehicles

Abstract: The transfer from conventional mining methods toward digitalization, automation and electrification is going on worldwide. The mining process efficiency needs to be improved in the future, because the mines are in more difficult places, far away from the infrastructure and very deep underground hence the high profitability is more difficult to achieve. Therefore, the mining process needs to be more energy efficient in the future to keep the business profitable. Accurate information about the productivity and process optimization is needed to achieve suitable decisions. The operation of mine needs to be modeled to find the most critical aspects in reliability and productivity point of view. In this study, an electric grid and mining vehicle traffic simulator, called MineGame, is created to model, visualize and study fleet-level operation of mine with simplified physics. Open source coding software is used to create easy-to-use tool to support complex decision making. MineGame enables the analyze of productivity and energy consumption of varying mining machine fleets, mine layouts, task management decisions and traffic rules. Engineers, who design mine operation, sale persons of mining devices and trainers may use MineGame.

Keywords: electric vehicle, mining, modeling, simulation, off-road vehicle

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1 Introduction

The use of electric mining vehicles will increase in the future due to more strict diesel exhaust regulation [1-3] and the efficiency of the whole mining process should be increased. Instead of improving only the efficiency of single vehicles, the overall understanding of the process productivity should be analyzed to find the most critical bottle necks. The fleet analysis tools exist for conventional diesel vehicles in mines and for electric on-road vehicles but not for electric off-road vehicles. The target of this study is to create simplified overall underground mine fleet analysis tool, called MineGame. The purpose of the dynamic mine process simulator is to study the productivity and energy consumption of mine depending on the used vehicles, traffic rules, mine layout, road conditions, driver skills and task management. The tool supports the customer in a) designing process of a new mine, b) during enlarging of an old mine and c) when making decisions of replacing existing fleet vehicles with new technology.

MineGame has been developed using open source Python programming language and it utilizes various available and free code packages to reduce the amount of commercial developer license fees. The inputs for the MineGame, shown in Fig. 1, can be divided in three classes: i) mine map, ii) simulation setup and runtime parameters and iii) task management.

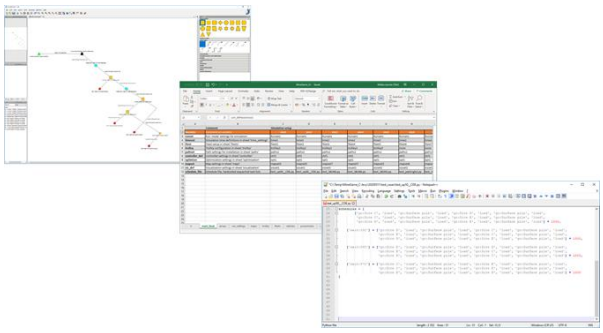

Fig. 1. Three classes of MineGame inputs: map, simulation parameters and task lists.

Event-based simulation of the fleet operation and mining efficiency is done in time scale of hours and days, hence it is not convenient nor required to model the system very accurately. Therefore, MineGame mechanics does not derive motion from force or power. Instead, an object in MineGame has motion based on its location, operating mode, environmental conditions and limitations and its internal limits. The needed power to maintain the motion against external resisting force can be then calculated. With the simplified

kinematics, the vehicle is always either stopped or at constant speed motion. In addition to that, so-called pseudo-dynamics are added to include the effect of acceleration and deceleration of the vehicles.

MineGame visualizes simulation results with an animation; a shift card , shown in Fig. 2a, and individual vehicle cards. The figure shows the time slots when each vehicle is in operation, waiting in traffic jam, waiting for charging, charging batteries etc. Moreover, the moved amount of rock and used energy are shown. The locations of traffic jams are visualized in Fig. 2b.

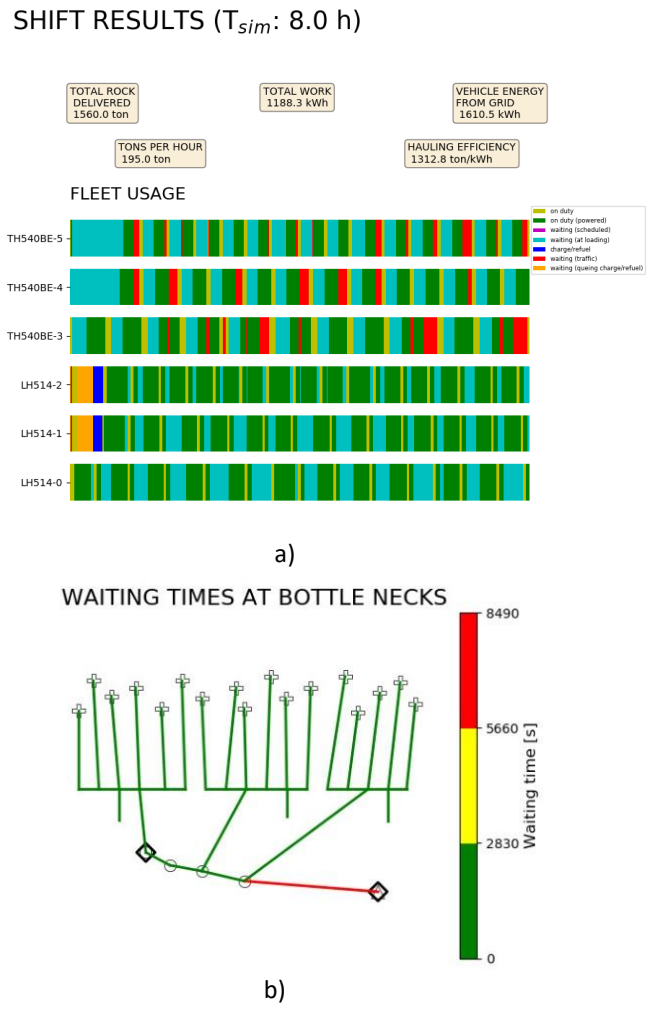

Fig. 2. MineGame result visualization with a) shift card and b) traffic jam in the studied map

In addition to productivity analysis, also the required mine electric grid can be analyzed by using the created tool. The energy consumption of each battery charging station is calculated in MineGame and the power consumption of other loads, such as drills and crushers, can be added to that. If the location and capacity of the transformers and cables is known, the loading conditions and maximum voltage drop of the grid can be calculated based on power flow calculation tool in Python. The example results are shown in Fig. 3.

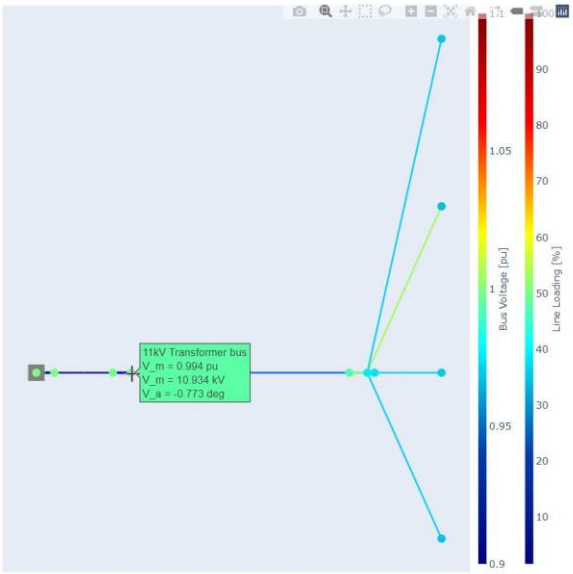

Fig. 3. Mine electric grid loading conditions and maximum voltage drop

2 Conclusions

The created MineGame is a mine process simulator concentrating to simulation of mine electric grid, electric underground mining vehicles and traffic. The purpose of the simulator is to study productivity and energy consumption of mine depending on the used vehicles, their battery charging method, traffic rules, driver skills, mine layout, road conditions and task management.

References

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