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Simulation and animation model to boost mining efficiency and enviro-friendly in multi-pit operations

Tarshizi Ebrahim [a,*], Sturgul John [b], Ibarra Virginia [a], Taylor Danny [a]

[a] Mining & Metallurgical Engineering Department, University of Nevada Reno, Reno 89557, USA
[b] School of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide 5005, Australia

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ABSTRACT

A discrete-event system simulation and animation program was developed to enhance the efficiency of a truck-excavator operation and reduce the environmental impact of haulage in an open-cut coal mine with multiple-pit operations. In any mine, a key objective is to have sufficient equipment for production and not to have excess to where it becomes counterproductive. Due to the advent of responsible mining, environmental regulations, and eco-friendly practices, these factors must also be considered in the analysis. Simulation studies can be financially advantageous for both the optimization of existing mine operations and new development phases in a mine. This study is a new approach to use discrete-event system simulation for mine systems, in order to investigate and possibly reduce environmental impact considering mining haulage performance and production target. A hypothetical layout of a surface coal mine with two pit operations was used for the simulation and animation model. The simulation model includes the animation of the operation. Animation is helpful to enhance the benefit of a mine simulation model. GPSS/H® and Proof Professional® were the software used for the investigation.

1. Introduction

The discrete-event system simulation and animation techniques of modeling mines can be a part of the R&D of Green Mining Technology to increase the mine operation's efficiency and reduce its environmental impact [1]. A typical large surface coal mine layout was designed and developed to illustrate the advantages of using discrete-event system simulation and animation to estimate and evaluate equipment needs for the mine haulage operation. Two coal mining operations were developed, namely pit 1 and pit 2, two excavators were assigned to pit 1 and four to pit 2 exclusively to mine the waste material in each pit. The coal removal fleet was not considered in the simulation and animation model.

The two pits served two separate waste areas and the overall layout is shown in Fig. 1. Twenty CAT 789C trucks and two Hitachi EX3600 excavators were assigned to pit 1 and 40 CAT 789C trucks and four Hitachi EX5500 hydraulic excavators were assigned to pit 2. The simulation model was used to determine the optimum number of trucks for each pit to maximize waste removal from the two pits.

* Corresponding author. Tel.: +1 906 4872582.
E-mail address: tarshizi@mtu.edu (E. Tarshizi).

2. Simulation and animation of a surface coal mine

Mining engineers need to take into consideration many uncertainties when designing, operating, and managing a mine. It is important to know the limitations, constraints, and other specifications of a mine to be able to maintain an optimal mining operation throughout the life of the mine. A mining operation takes a large amount of capital both in develop and during the life of mine. The process of analyzing a mine's existing operation and possible alternatives that can be implemented, will prevent unnecessary expenditures in replacing and purchasing new equipment [2]. A discrete-event system simulation model of a mining operation is one of the most powerful and insightful tools that can assist engineers to analyze alternatives before making a change in the proposed plans and both capital and operating budgets.

The software used for modeling this mining operation was GPSS/H®, a simulation programming language; Proof Professional® was used for the animation. The software is produced by Wolverine Software. GPSS/H® was used due to its low level programming language, cost effectiveness, fast processing, and extreme flexibility to model complex discrete systems (such as mines) [3].

Proof Professional® software facilitates a visual model of the simulation over time. The drawing tools provided in Proof allow

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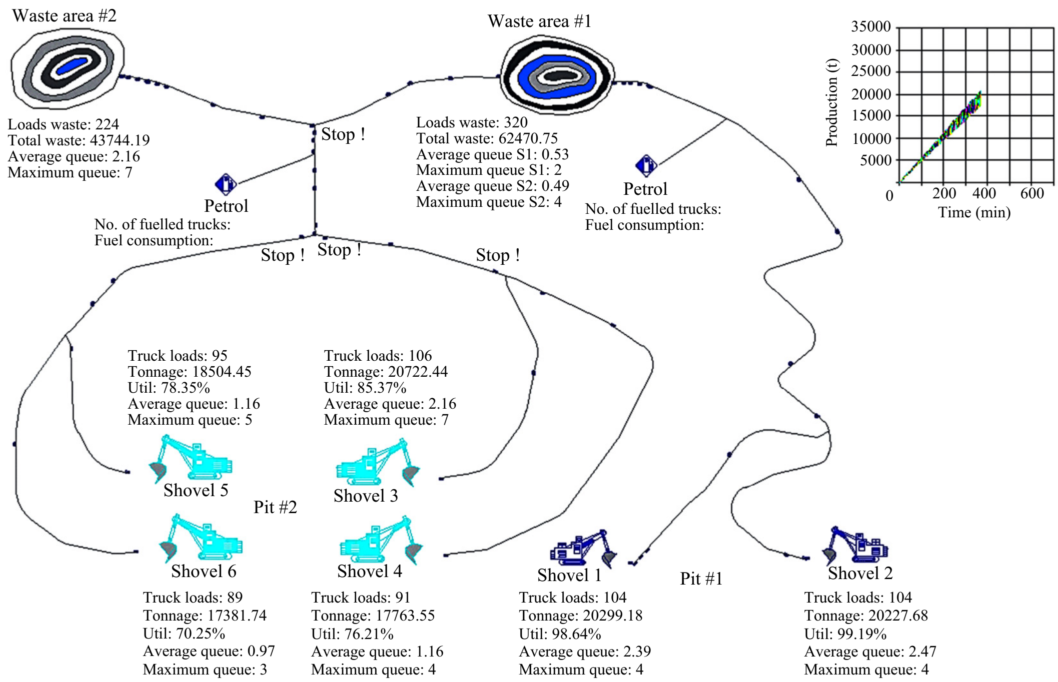

Fig. 1. Animation of the simulation model of a surface coal mine.

for an animation to be nearly realistic. Proof also has the ability to import and export CAD files and the capability of zooming in and out without losing the images' sharp quality [4]. If there is an error in the code or animation, the modeler(s) can easily catch it visually by running the animation after the simulation.

The developed simulation and animation program represents a model of the mining operation. It includes a screen display of the total production throughout the shift and a graph for each excavator showing loads, tonnage, utilization, and queue size. The screen includes a clock that shows the simulation time in minutes, hours, days and weeks. In addition, the number of trucks allocated to each shovel, total number of trucks, and shifts are shown for the convenience of the users. "STOP" signs are displayed on the animation when and where the trucks need to stop at the intersections for an appropriate time. Pit 1 can send trucks to both waste dumps but pit 2 only to one waste dump, but the dumping locations are independent for each pit (see Fig. 1). The model plots the shovels' production (tonnes) versus time (min). Each shovel is displayed by different recognizable colors on the plot to make the production studies of the shovels easier to see on the screen [5].

The output of the computer simulation includes the following:

- Number of loads from each excavator.
- Loads per truck.
- Excavator utilization.
- Number of trucks in excavator and waste area queues.
- Number of loads arriving at each waste area.
- Total waste production.

The logic of the mine overburden removal operation is as follows: empty trucks are loaded by the excavators; loaded trucks haul waste to the assigned areas; after dumping, they return to the excavators assigned by a Dispatch system. This system decides at each of the four intersections which excavator a truck is assigned to by looking at the number of trucks at each excavator and the estimated wait and load time. It also takes into account the time to travel from the intersection to the excavator. Only one truck can dump at a time in both waste areas owing to a constrained dumping area.

The simulation model consists of 270 separate paths/travel segments. Each segment has a separate normal distribution for the travel time. Loading and spotting were modeled using a normal distribution, and breakdowns were modeled using an exponential distribution.

The simulation and animation model of the mine operation was uploaded on a secured website (with a username and password) as a part of WEB-based simulation project, which is in its infancy. An interactive secure content management website was designed and launched for this purpose. If the simulation and animation can be posted on a website so that a remote user/mining engineer might be able to easily interact with the model and pose the "what if?" questions, it will add greatly to the applicability of a simulation program. This was not conducted before for a mining simulation. WEB-based simulation for mining is a new and fertile area [5].

3. Coal mine simulation results and analysis

Different scenarios were assessed that involved changing the number of trucks assigned to each excavator. Several scenarios in combination were run using 13–20 trucks in pit 1 and 40–44 trucks in pit 2, in order to compare results. Fig. 2 illustrates the number of loads when the number of trucks was increased in pit 1 and pit 2. In both pit 1 and pit 2, the largest rate of increase in loads occurred in the beginning when one truck was added. Gradually the rate of change decreased, and eventually, the number of loads decreased when pit 1 operated with 20 trucks.

Fig. 3 demonstrates the utilization of each excavator when the number of operating trucks was increased in pit 1 and pit 2 respectively. The utilization of excavators was calculated according to the following definition:

$$\text{Utilization } (\%) = \text{Excavator's operation hours}/(\text{Total hours} - \text{standby hours}) \times 100 \qquad (1)$$

In pit 1, the rate of increase (slope) in utilization was high for the first three trucks added, after which the rate of change was marginal. On the other hand, pit 2's rate of increase was minimal.