A SPECIALIZED LIBRARY FOR SIMULATION OF COAL MINING IN FLAT-LYING COAL SEAM

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ABSTRACT

The paper describes a new specialized library of simulation models of mining machinery for coal mining in flat-lying coal seam. This library is a part of the new visual interactive discrete simulation system of technological processes MTSS (Manufacturing and Transportation Simulation System). MTSS is effective in solving the task for the rapid creation of correct simulation model by mining engineers. This is ensured by the presence in the simulation system visually interactive interface and a set of libraries. There are libraries for simulation the following subsystems of coal mine: belt conveyor subsystem, power supply subsystem, and pumping subsystem. The new library contains models of highwall mining, longwall mining system, coal seam, mining machines, self-moving coal wagon, and storage area. Models of highwall technology and longwall technology for coal mining in flat-lying coal seam were made with the help of the new library. These models are used for developing of process control systems for underground coal mines in Kuznetsk Coal Basin (Russia, Western Siberia).

Keywords: visual interactive simulation, coal mining, longwall mining, highwall mining

1. INTRODUCTION

It is specified in different investigations, that situation in different areas of underground mining that requires automatic control (e.g. coal mining) is that resources become less available, and harder to be extracted.

The technologies of coal mining are well-known. Today mine uses mining machinery for mining, transportation, roof support, etc. How exactly will these machines function? What additional machines will they require? What is the cost of machines installed in mine? Will big universal machines be more appropriate rather than a lot of small, specialized mechanisms? What will the cost of a final product be? These tasks can be solved by methods of computer-based simulation of coal mining process.

The problem of the particular mining installation is that it is effective in terms of minimum costs and maximum productivity only if it is correctly planned. Usually big layout has many components from different vendors interconnected. That makes it hard or, even, impossible to predict the exact effectiveness. This situation gets worse if there is also a requirement to create new components for management of a part of such layout. In all these cases, computer-based simulation can be used to solve these problems.

Because of the importance of these problems, there are a large number of papers on the use of simulation in the development and optimization of coal mining systems (Sturgul 2001; Kizil et al. 2011; Greberg and Sundqvist 2011; Cai et al. 2012; Fioroni et al. 2014). There are also a large number of simulation tools both universal simulation systems and specialized systems and packages for simulation of coal mining systems.

A number of models for various technologies of coal mining were developed with the help of own simulation system. Technologies of coal mining are presented in section 2. Brief description of the simulation system is presented in section 3. Sections 4, 5 contain description of a specialized library and examples of the models.

These models are used for developing of process control systems for underground coal mines in Kuznetsk Coal Basin (Russia, Western Siberia).

2. TECHNOLOGIES OF COAL MINING

There are several well-known technologies of coal mining.

2.1. Longwall mining

Longwall mining system is a highly-automated, very powerful and productive way to mine a product. It is most-widely applied around the world. Its main advantage is that it leaves almost no product inside mines. But it is limited with the depth of the mine (measured from the surface). Also it is applied in relatively flat areas of coal, from 0.8 up to 10 meters high, from 150 to 450 meters face, and up to 4 kilometers in depth.

Longwall system consists at least of armored face conveyor (AFC), a shearer, and roof support sections. The AFC is connected to outbound belt conveyor. The shearer cuts the product from coal seam face, in a series of passes along the AFC. The AFC delivers product to the belt conveyor connected. The roof support moves itself and the AFC, pushing it (and itself) forward with hydraulics. One of the problems of longwall mining is roof caving. This can lead to serious environmental problems. The other problem is that longwall requires significant amount of work to be done before its massive equipment will be installed in production. This work also must be planned.

2.2. Highwall mining

In case when it is impossible to mine a product with longwall or other systems, a relatively new technology can be applied, named Highwall. This is a shearer tool, mounted on the top of the chain of special sections. These sections can be updated to each other, making a long (up to 300 meters) support chain for a shearer. Each section can transport the product developed by shearer to the end of a sections chain.

The shearer and the chain of sections cut the product (coal) from the very thin and curved seams. This is the main advantage of the Highwall technology.

2.3. Coal mining of flat-laying coal seam

This approach uses a number of front-cutting mining machines that cut a coal on a special scheme, and a number of self-moving wagons that move a coal from mining machines to the storage area. It solves the same problem as highwall mining, but requires no specialized equipment. Also this approach can be used in deep mining.

3. THE SIMULATION SYSTEM

A visual interactive Manufacturing and Transportation Simulation System (MTSS) is developed at Design Technological Institute of Digital Techniques of Siberian Branch of the Russian Academy of Sciences (DTIDT). It is a process-oriented discrete simulation system intended to the development and execution of models of technological processes (Okolnishnikov et al. 2010a, 2010b; Okolnishnikov 2011).

MTSS is a set of program interfaces for creating elementary models and for forming complex models from them. The elementary model is a ready-to-use submodel of an equipment unit with capability of low-level control for it.

The elementary model consists of the following parts:

- Two-dimensional and three-dimensional graphic images.
- Input and output parameters.
- Functionality algorithm describing dependence between parameters.
- States which the elementary model can reach during the simulation process.
- Control commands defining switching process between elementary models states.

A model in MTSS is created by graphical connection of images of elementary models.

MTSS is also a tool for running of complex models built from elementary models. The running model performs the movement of the model time and visualization. Statistics is collected as well. Statistics are available as a short overview when model runs, and more statistics are available after model completion.

This simulation system is effective in solving the task for the rapid creation of correct simulation model by mining engineers. Usually engineers have not enough qualification to create a simulation models in details, but they know how to connect correctly elementary models to create the required topology. MTSS uses the 2D as the graphical editor and 2D, 3D for the visualization of model running. Such approach seems more natural for mining engineers, when all installations and machines appear first on 2D plans. 3D is more useful for visualizing complex vertical movement.

Process control systems often have two levels: the low level of equipment and simple control logic and the upper level of complex control of production. Therefore one of the distinguishing features of MTSS is a separation of the logic of simulation model into two parts: low-level logic and an upper level logic.

Such separation allows us not only to correspond to the usual structure of the process control systems but to use such models for embedding them into actual process control systems in the following ways: to emulate equipment, to simulate upper level logic, and to send commands to actual process control system for debugging and testing. This separation into upper and lower logics allows also organizing a switch between various implementations of the decomposition. It allows coexisting simulation of upper level logic and a proxy that allows communicating with the upper level logic of actual process control system.

The model of coal mining can communicate with a new process control system developed in DTIDT, to be a source of input signals, emulate equipment, test actual control program with simultaneous visualization of overall process of mining.

This allows debugging and tuning of a new process control system in accordance with behavior of simulated system, even allows simulating various accidents. This allows minimizing time and costs on site for commissioning.

4. SIMULATION OF COAL MINING IN FLAT-LYING COAL SEAM

A specialized library of simulation models of mining machines for coal mining was developed. This library is a part of MTSS and its prime goal is to simulate interactively and visualize various aspects of coal mining in flat-lying coal seam. The library consists of new elementary models of:

- Highwall mining system.
- Longwall mining system.
- Coal seam.
- Mining machines.
- Self-moving coal wagon.
- Storage area.

The library contains also a simulation model of a flat-lying coal seam. This model is a source of the product in a simulation model, while storage area is a consumer of a product. The product itself is coal.
These new components can communicate with existing libraries of MTSS (Okolnishnikov et al. 2013a, 2013b) which simulate mines subsystems like:

- Belt conveyor subsystem.
- Power supply subsystem.
- Ventilation subsystem.
- Pumping subsystem.

A simulation model of coal mining subsystem in a flat-lying coal seam was developed using the library of mining machines. Figure 1 contents a sample layout in the simulation model of the flat-lying coal seam (2D and 3D view combined in different views).

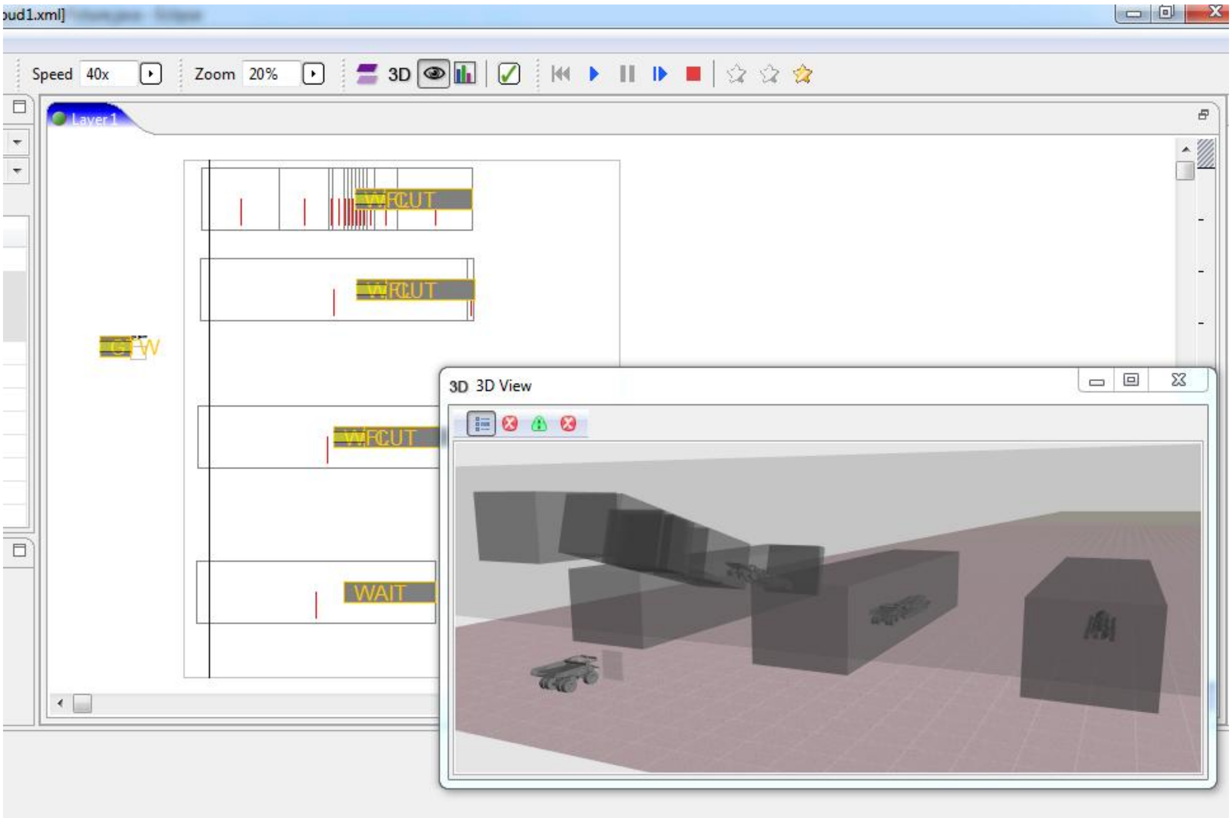

Figure 1: Simulation model of coal mining in flat-lying coal seam (4 mining machines and 4 self-moving coal wagons)

The simulation model built from the content of the library will simulate movement of all mobile objects of the model. Both 2D (top view) and 3D visualization are available. Statistical data is also collected.
Figure 2 shows a sample layout in another simulation model of the flat-lying coal seam. Main window consists of 6 areas:

1. 2D top view. It contains: main mine, side mines. The origin coordinates is at the left top corner of this view.
2. 3D view. On Fig. 2 there is a view from point 3).
3. Point of view for the 3D.
4. Parameters of a simulation model.
5. Specialized view for fast navigation in simulation model.
6. Settings for the time start, time end and current model time.

The model was created to visualize new technology of coal-mining in flat-lying coal seam (Fedorin et al. 2013). This simulation model also allows receiving statistical results for usage of this technology.
As patent describes, mining is done by frontal winning machine, paired with self-moving coal wagons. Patent describes the directions of cut of a flat-lying coal seam for the frontal winning machine. Simulation model of this process allows visualizing the process described.

5. SIMULATION OF LONGWALL MINING

For detailed simulation of longwall mining system we finished with next decomposition: armored face conveyor, shearer, and roof support sections.
Simulation model for longwall mining system can function only if it is connected (in terms of MTSS) with belt conveyor simulation model.

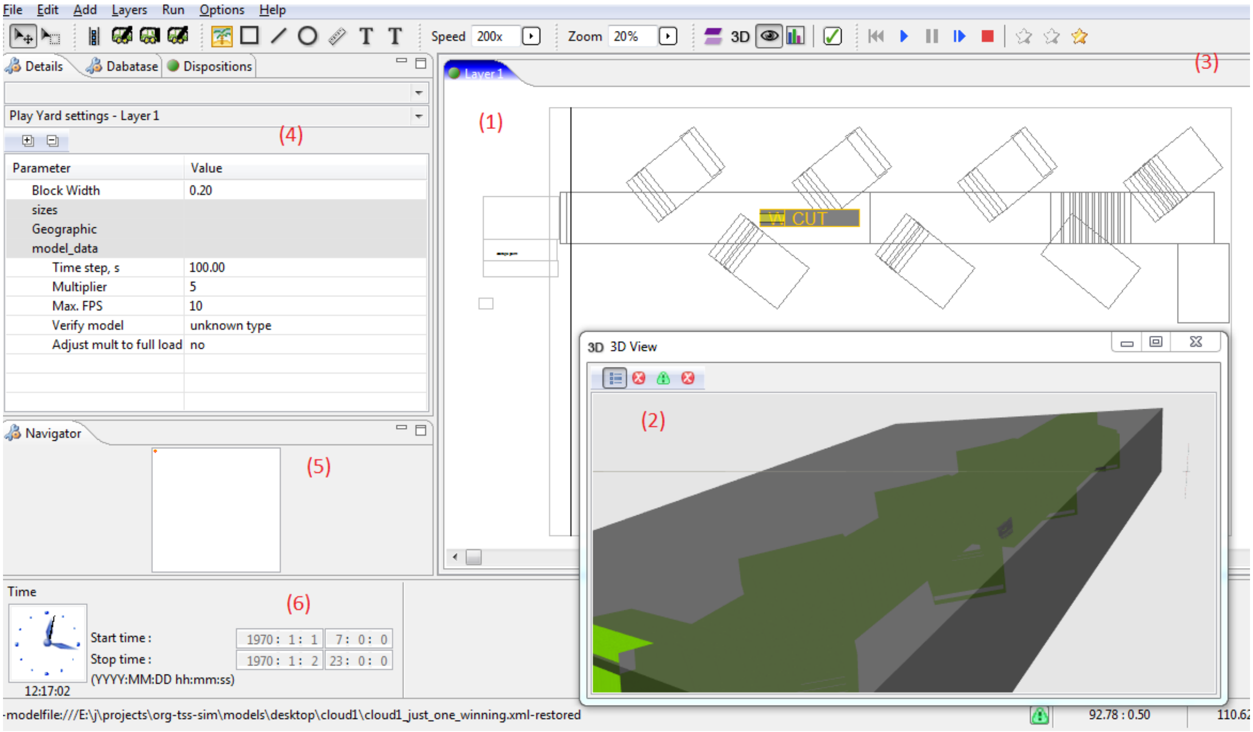

Figure 2: Main window of MTSS system while running of simulation model of coal mining in flat-lying coal seam

The algorithm for longwall mining system simulation is done closer to the control algorithms of the real longwall mining system. The task will define the amount of time for the shearer to move to the state while it will allow one roof support section to be free to move, and an amount of a product to be mined. Then it will advance the simulation to the time defined, and then simulate the roof support sections movement. The amount of a product will be moved to the AFC that will deliver it to the belt conveyor. Task will repeat these steps until the "done" or "postpone" conditions will be achieved.
Task is "done" when shearer reaches the end of an AFC line. Task is "postponed" when belt conveyor is overloaded and cannot accept the next portion of product or gas level is not safe.
During any of these steps, the simulation model of flat-lying coal seam will simulate roof fall (behind the roof support) and gas level increasing. Also ventilation simulated (remove gas from working area).
In most cases, there is no need to simulate in details any technology like longwall or flat-lying coal mining, if it is used just as a source of a product for belt conveyor system, for example. All that is really needed in such cases are:

- To define that longwall or flat-lying coal mining is a source of a product for a big mining system like conveyor.
- To know the performance of the longwall coal mining during some time period (working day, 8-hours time interval, 1-hour time interval). Note that the emergency stops (like gas or coal dust) are already included in this statistical data.

But if the goals of simulation are:

- To predict how longwall or flat-lying coal seam mining automation will behave in details (i.e. movement of its parts depending on various situations in mines).
- To make a detailed visualization of mining process.
- To define how this mining will impact to the overall performance of the mines.
- To define scenarios of broken or temporarily inaccessible parts interactively.

Then achieving these goals will require detailed decomposition of common longwall (or highwall) mining system and a detailed visualization of all its parts.
In our work both detailed and statistical approaches are presented.

6. FUTURE WORK

Detailed simulation of longwall system, connected with detailed simulation of flat-lying coal seam (or multiple flat-lying coal seams), will allow creating of simulation that will not only predict the behavior of big underground mining system, but also simulation of land subsidence while using longwall, especially with very heavy longwall systems that can cut 10-meters-high coal seams.

Simulation system MTSS can be used not only for simulation of existing coal mining techniques but also for perspective robotized techniques.

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REFERENCES

Cai D., Baafi E. and Porter I., 2012. Modelling a longwall production system using flexsim 3D simulation software. Proceedings of 21st International Symposium on Mine Planning and Equipment Selection (MPES 2012), pp. 107-114. November 28-30, New Delhi, India.

Fedorin V., Shachmatov V., Anferov B. and Kuznetsova L., 2013. The method of open-underground mining of thick flat coal seam. Patent for invention of Russian Federation № 2490456.

Fioroni M., Santos L., Franzese L., Santana I., Telles G., Seixas J., Penna B. and Alkmim G., 2014. Logistic Evaluation of an Underground mine Using Simulation. Proceedings of the 2014 Winter Simulation Conference, pp. 1855-1865. December 07-10, Savannah, GA, USA.

Greberg J. and Sundqvist F., 2011. Simulation as a tool for mine planning. Proceedings of Second International Future Mining Conference, pp 273-278. November 22-23, Sydney, New South Wales.

Kizil M.S., McAllister A. and Pascoe R., 2011. Simulation of Development in Longwall Coal Mines. Proceedings of the 11th Underground Coal Operators' Conference, pp. 91-98. February 10-11, Wollongong, NSW, Australia.

Okolnishnikov V., Rudometov S. and Zhuravlev S., 2010a. Simulation environment for industrial and transportation systems. Proceedings of the International Conference on Modelling and Simulation, pp. 161-165. June 22-25, Prague, Czech Republic.

Okolnishnikov V., Rudometov S. and Zhuravlev S., 2010b. Monitoring System Development Using Simulation. Proceedings of the 2010 IEEE Region 8 International Conference, vol. II, pp. 736–739. July 11-15, Irkutsk, Russia.

Okolnishnikov V., 2011. Development of Process Control Systems with the Use of Emulation Models. International Journal of Mathematics and Computers in Simulation, issue 6, vol. 5, pp. 553 – 560.

Okolnishnikov V., Rudometov S. and Zhuravlev S., 2013. Simulation Environment for Development of Automated Process Control System in Coal Mining. Proceedings of the 2013 International Conference on Systems, Control, Signal Processing and Informatics, pp. 285–288. July 16-19, Rhodes Island, Greece.

Okolnishnikov V., Rudometov S. and Zhuravlev S., 2013. Simulation Environment for Development of Automated Process Control System in Coal Mining. International Journal of Systems Applications, Engineering & Development, issue 5, vol. 7, pp. 255–262.

Sturgul J.R., 2001. Modelling and Simulation in Mining - Its Time Has Finally Arrived. Simulation, 76(5), pp. 286-288.