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Simulation Environment for Development of Automated Process Control System in Coal Mining

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***Abstract*—This paper describes a visual interactive simulation system of technological processes intended for the development and execution of simulation and emulation models for automated process control systems in coal mining. A set of simulation models of various subsystems of a mine was developed with the help of this simulation system. These models united to create simulation environment. Simulation environment is visually interactive, include emulation models of technological equipment and allow simulating complex situations in mines and working faces. Simulation environment was used for testing of control programs executed in programmable logic controllers.**

***Keywords*—visual interactive simulation; coal mining, automated process control system**

I. Introduction

A number of Automated Process Control Systems (APCS) for different industries like coal mining and oil mining is being developed at DTIDT. Among others the following problems arise during the development of such systems. The complete testing of control system using the programmer's tools prior to commissioning is almost impossible because of inability to connect with real equipment and because of inability to reproduce an operational situation and emergencies.

The most suitable way to solve these problems is simulation. A means for solving these problems is a model integrated with an actual APCS. The model can be run as a part of an actual APCS. On the other hand the model can include software or hardware components of the actual control system, for example, control programs or a programmable logic controller (PLC) in which the control programs executed. This model should also include a model of technological equipment. Such model is known as an emulation model [1].

There are many examples of the use of emulation models for testing automated production lines or automated material handling systems [2]–[4].

This paper describes the use of simulation and emulation models for developing of industrial APCS of underground coal mining (Kemerovo region, Kuzbass, Russia).

Today the technology of coal mining is well developed. But the state of the industry requires and the state of the science permits to make a quality move in tool development for mining. It is now possible to make this branch really safe, and product mined – really cheap. One of the ways to reach it is to robotize mining [5].

In this case robotize means to invent mining and supporting machines that can fully replace a human under the ground. This possibly requires the creation of intellectual machines that can make simple or complicated solution. Such mechanisms are usually called robots.

Robots will allow not only replace humans under the ground but require less supporting background: they can work at very high temperatures, with very high percentage of dangerous gases in atmosphere. The production unit of such robots can the underground gas to get the energy right under the ground, without need to plug them to ground power stations, and loose a significant amount of energy while power transmission deep under the ground. The coal can be separated also under the ground, with rock refuse being placed into empty mine parts.

Today mines use the approaches that can be recognized as robotized (Highwall systems). Main mechanical elements inside the mines are still machines for mining, transportation, and support installation and control.

Also there are a lot of additional machines (generators, transporters) required to organize fully functioning industrial mine.

How exactly will these machines function, what additional machines will they require, what is the cost of machines in stalled in mine, how to organize the delivery of spare parts for these machines? Will big universal machine be more appropriate rather than a lot of small, specialized mechanisms? What will the cost of a final product be? These questions can be answered by the method of computer simulation of coal mining process.

For solution of these problems a set of simulation models of various subsystems of coal mining was developed with the help of the new visual interactive simulation system of technological processes. These models were developed with the goal to be used as a quality assurance tool for new APCS of coal mining. These models of various subsystems of coal mining were united to create simulation environment of coal mining.

Simulation environment includes also emulation models of technological equipment and allow to simulate complex situations in mines and working faces visually as well as to check the response of APCS developed for these situations. Simulation environment was used for testing of control programs executed in PLC prior to commissioning.

II. Visual Interactive Simulation System of Technological Processes

At present there are a large number of simulation systems and libraries used for simulation of technological systems. But most important is that all these systems can be used just by specialists in simulation. Computer-based simulation is complex. Only specialists in simulation able to make a decomposition of original problem, create simulation experiments, validate and verify models, and most important to make a backward decomposition and analysis of simulation results to final users (subject matter experts).

In the latest 10 years a number of simulation systems appeared that subject matter experts can use (ProModel, WITNESS). But these systems are built based on existing, previous versions of the same products that are only for specialists in simulation. As a rule, interface of such system is untouched, only some subject-oriented components added. And these systems still relies on decomposition of original technological systems like in a raw simulation. But today computers are not limited in memory and processor resources, they are very good with user interfaces, and they allow creating simulation experiments with very detailed simulation models, with detailed and informative graphical representation.

At present simulation tools are required for rapid development of models for various industrial applications [6]. Such models can be used as parts of actual APCS for developing, testing, optimization, and operator training [7]–[9]. They can be also used in marketing to present some industry solutions to the customers.

One of the requirements is to reduce or to exclude the participation of specialists in simulation in the process of the simulation model contraction. It is required to ensure transparent access to simulation environment for the specialists from application area having minimal knowledge in information technologies [10].

These requirements were taken into account while designing a new visual interactive simulation system of technological processes MTSS (Manufacturing and Transportation Simulation System) [11]–[14]. It allows building simulation models, using simulation models of technological equipment and a coal layer. The simulation model for coal mining can be created from simulation models of technological equipment, connected with each other and with simulation model of the coal layer. The coal layer can be set with its linear sizes, placed into the geographical coordinates. Various zones in a layer model can have different properties (amount of coal, quality of coal, etc).

The key point in MTSS is an Equipment Model (EM). EM is a simulation model of a technological object in a technological system. It consists of the following parts:

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

EM development process consists of creation a conceptual model of a technological object and its automatic translation into Java in accordance with EM structure in MTSS.

Images of different EMs can be connected to each other visually with the help of graphical port mechanism. Such approach allows building models of complex technological systems using models of contained technological objects.

As a rule each mine has a plan of mining. Such plan is usually created after the scientific investigation of a land zone. In simulation model such plan can be described as linear segments connected to each other by their ends. Mining machine can mine the coal only near each linear segment where it is currently placed. So the coal layer can be simulated as a set of connected linear segments, with coal placed around these segments only at the distance reached by mining machines. The amount, density, amount of gas, etc of the coal in model can be varied.

Changing the "density" property it is possible to define whether the product is coal or rock. Changing the "amount of gas" parameter it is possible to define how fast the amount of gas will increase while mining. This will define moments when mining must be stopped and mines filled with fresh air.

Mining machine (MM) is the main technological equipment for simulation of working face. Existing mining machines as well as perspective robotized mining machines need a possibility to specify various parameters in a model, like the following:

- Dimensions of MM.
- Weight of MM.
- Performance of MM.
- Type of control.
- Presence of special tools for coal layer properties measurement.
- Presence of connected fastener system.
- Embedded conveyor with machines for its automatic enlargement, etc.

In addition to the model of working face there were developed models of other subsystems of the mine: a model of belt conveyor network, a model of drainage subsystem, and a model of electric power supply.

Main possibilities that are provided by MTSS are: rapid visual interactive building of models from EMs, 3D representation, and the communication of models with actual APCS.

III. Simulation Environment

Simulation environment to test control programs executed in PLC is developed. PLC is a part of APCS. Testing control programs executed in PLC prior to commissioning It reduces the time and the cost of testing and optimization APCS.

The structure of this environment is shown in Fig. 1. It consists of:

- MTSS workstation which allows the users to work with simulation models of technological equipment and technological processes of actual system.
- SCADA workstation is a place of APCS operator.
- The communication environment for data transmission is designed to send data between workstations, controllers and (if system is already deployed) technological equipment. If controller has a direct connection with technological equipment (i.e. it has analogous and discrete ports for input and output signals), a special communication convertor is added to allow testing. This convertor will transform notification signals into analogue and discrete signals, and visa versa.
- A PLC is tested equipment.
- Sensors and actuators of technological equipment are the part of simulation environment in case of its usage as a part of a Solution Support System (part of APCS).

There are a number of simulation models what were developed. They are a part of MTSS workstation and they are used both as a s ource of control signals and sensor states. Simulation environment can function in the next modes:

- Testing. This mode is used to check control programs in the frames of APCS.
- Investigation. The mode is used to research the algorithms of control programs in the frames of APCS. The goal of the mode is to predict the values for various (all) technological parameters predict the consequences of in the case of emergency and develop the operator actions to prevent the cases themselves.
- Education. The mode can be used to teach and certificate the operators of APCS.
- Solution support mode. It is used to evaluate various control actions made by an operator of APCS on simulation model before the actual commands are made.

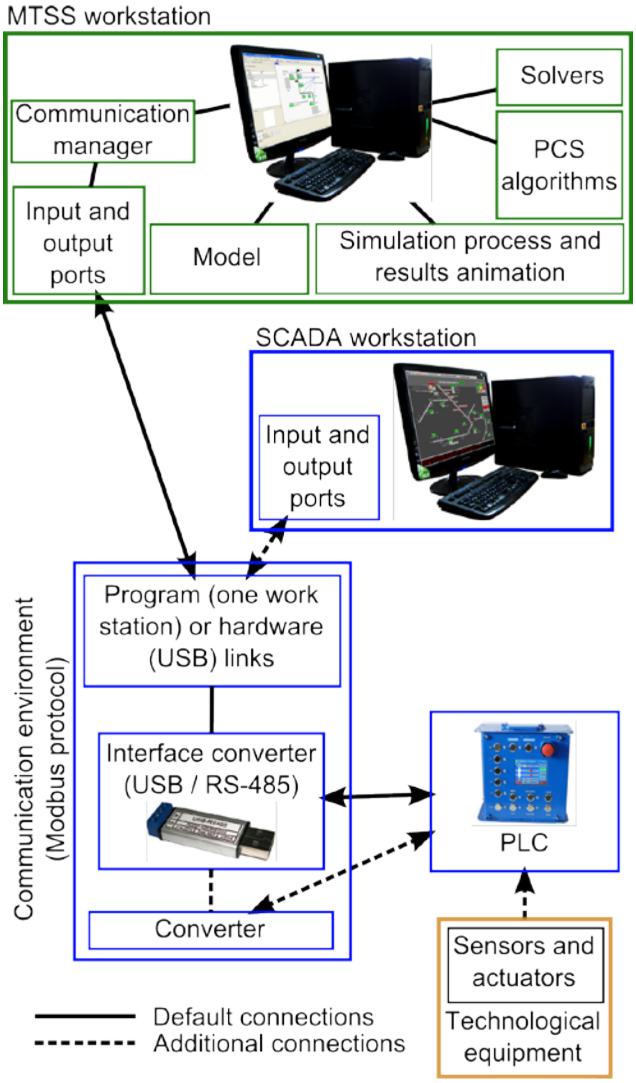

Fig. 1. The structure of the simulation environment.

Several modes of operation of the simulation environment are shown in Fig. 2.

There are three modes of operation of the simulation environment: a technological process simulation, a controller testing and real and simulation control program comparing.

Control command starts an execution of a m odel a technological process in MTSS. Then the command is processed in accordance with the model of the control program. State change is shown in the animation window of MTSS.

While the controller testing mode the command goes to a communication manager. The manager realizes that information is transmitted between the controller and the model of the technological equipment with use a module of conversion. This module converts the data which transferred to the controller from the model and vice versa. The data that transmitted from the model is processed in the controller. Controller creates control signals for actuators. These signals entered the communication manager.

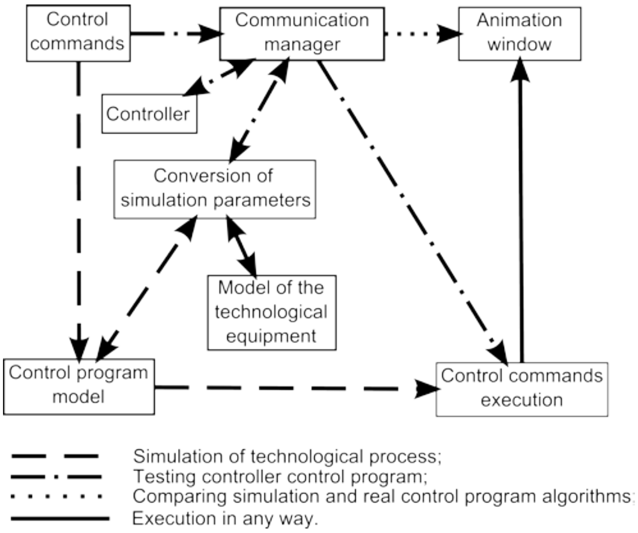

Fig. 2. The operation of the simulation environment.

Converted control signals are executing in the simulation system. Changing the state of the model is showing in the animation window of MTSS.

There are two independents steps in comparing mode – simulation of the technological process and testing of the controller. First step is simulation of the technological equipment. This step is the same as the simulation mode. Second step consists of execution of the control command in the controller program logic and animation of control actions. Simulation results and the actual results of the execution of the control programs are presented separately.

IV. Conclusion

The Java and Eclipse RCP is used as a technology and a platform for implementation of MTSS. Such selection allows having portable implementation on many platforms. Also Java technology is good enough to meet all needs, including performance and graphics (2D and 3D).

One of the tasks solved using MTSS is the creation of a simulation model of the underground perspective mining. Current version of this model allows creating investigations of configurations of a working face (amount of mechanisms, energy consumption). It is possible to combine simulation of working face with simulation of other areas of working face and underground mining (electric power supply, drainage, belt conveyors) to create very complex and detailed models of mining industry. These models are visual and interactive. Today the primary goal of these simulations is to provide a source of emergency situations for developing of APCS.

MTSS allows development of simulation environment that makes in possible to create very detailed and reliable simulation models by subject matter experts who are not familiar with computer-based simulation.

Simulation environment can be used not only for existing coal mining techniques but also for perspective (robotized) techniques.

MTSS started as a simulation environment for technological systems. But its applications are not limited only by technological systems itself. Specialist in simulation can build libraries of EMs for wider range of systems by using capabilities of MTSS. Example is the library of EMs for computer simulation of complex computational network.

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