A modern vision of simulation modelling in mining and near mining activity

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Abstract. The paper represents the creation of the software simulation system, which reproduce the basic processes of mining and near production. It presents the consideration of such systems for both traditional and non-traditional mineral extraction systems. The principles of using computer recognition of processes are also presented in other processes of carbon-containing raw materials transition, as well as power production and waste utilization of mining production. These systems considerably expand the manageability of a rather complicated mining enterprise. The main purpose of such research is the simulation reproduction of all technological processors associated with the activity of mining enterprises on the display of the dispatch center. For this purpose, is used so-called UML-diagrams, which allows to simulate mining and near mining processes. Results of this investigation were included to the Roman Dychkovskyi thesis of the scientific degree of the Doctor of the Technique Sciences "Scientific Principles of Technologies Combination for Coal Mining in Weakly Metamorphoses Rockmass".

1 Introduction

Mine technological systems represent an ordered set of objects, the functioning of which in time and space implements a complete technological cycle of underground mining method. One of the main parts of technological system is a net of underground mining works that provide the preparation of reserves for processing, transportation of extracted raw materials, ventilation and delivery of people and materials [1 – 4].

The dynamic development of mining operations, the presence of various geodynamic stressed fields in anisotropic environment, the variation of the geological and structural formation of an array in the way of moving of a treatment face leads to the necessity of making adequate changes in mining technology and rock pressure control methods. The efficiency of operation of mechanized complexes depends on timely predicted correction of

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technological parameters and technical composition, an adequate change in the geo-mechanical situation at mining site.

The assessment of mining and technical situation during implementation of new radical mining technologies [3 – 11], change of physical and chemical properties under the influence of external factors [12, 13] is especially important. Extraction of minerals in complicated mining and geological conditions also are presented on specialized literature [14 – 16]. Detailed description of the mechanism which is using the method of final elements for determine the stresses in rock mass, and is proper for simulating the process of underground coal gasification is presented at works [3, 17, 18].

On the way of formation of man-made space in the mineral extraction the geo-mechanical situation may change within one mining area. Mining works develop dynamically into the depth of a rock array, and man-made stress fields are layered in the same direction. The presence of various geodynamic stressed fields in anisotropic geological environment influences the direction of the resulting stress vector having a different value depending on its orientation in the array. The development of mining works can be correlated differently to the highest values of the stress vector and this affects the stability of mining works. The entire mining equipment operation under these conditions depends on timely predicted correction of technological parameters in accordance with changes in the geo-mechanical situation [19 – 21].

The same situation is observed when mining production is curtailed. Utilization of waste, sewage or mine water requires continuous monitoring of this process. Any malfunction leads to significant surface contamination and adversely affects the flora and fauna of the after-mining areas [22, 23, 24].

Analysis of mining and geological conditions, geo-mechanical, mining and technical factors provide the opportunity to obtain data to determine technological parameters of all processes associated with mining. Solution of this task is provided by simulation modelling of production processes in a mine, taking into account changes in mining and geological, technological, mining and technical factors.

2 Source simulation data

Essence of software simulation processes of mining is presented at [3, 25]. So it is mentioned that creation of simulating model of all mine in the specified volumes demands not only big efforts at the level of the developed structure of programmers, but also high system opportunities of the software. Therefore, at design of such difficult information system it is offered to break it into components, each of which is considered separately. Two various ways of such splitting into subsystems are possible: structural (or functional) splitting and object (component) decomposition.

The structure of simulation modeling is divided into three sectors [26]. "The perfect idea" corresponds real value of object nature. This sector is ideal reproduction of process of modeling. When modeling, actually, has no opportunity to reach 100% convergence to results of "perfect idea"; it is possible to approach the received results to real conditions as much as possible only. The "zone of variable data" is changeable. Its purpose is the object adaptation – model to real object by means of comparison of fictitious results of model to real results in the conditions of mine. It is necessary in the course of modeling. The "zone of accidents" is sector of modeling at which the validity of process of modeling isn't observed. It is considered that here has no compliance of results of modeling.

The direction of increase of reliability of results of modeling is indicated the need as much as possible precisely to correspond sector by "perfect idea" is real value of modeling. A new interpretation of evolution of technologies and prospects of research with using big data can be also applied [27].

Use of simulation modeling in terms of modern mine is based upon the simulation representation of all its qualitative and quantitative characteristics: type and structure of a mine; mining techniques; schemes of mine field opening; mining systems; sequence of seam mining; plan of reserves extraction; types of underground transport; schemes and types of mine ventilation; number of mine field blocks within a simultaneous operation; number of levels and sublevels within a mine field and sequence of their extraction; number of panel mine sections within a level; number of seams and stopes being developed simultaneously; number of working days per year and mining shifts per day; number of hours per shift; sizes of mine fields and blocks; sizes of levels, panels, mine sections; length of longwalls and extraction pillars; advance rate of stopes; loads upon stopes, levels, panels, blocks; mine capacity; section areas of mine workings etc. The same situation is when we are going to simulate near mining processes. It is necessary to mentioned that should be simple and understandable to the performer.

3 System of functional representation

So-called activity diagrams are used to model the processes of operation performance in UML language. Graphical component used in them is like the state diagrams as the activity diagrams also contain the symbols of stationary states and qualitative transitions of the system. The difference is in the semantics of states and in the nonavailability of event signatures within the transitions. Each action of the diagram corresponds to the performance of some elementary operation; transition to the following state is possible only after the certain goal reaching. Graphically, the activity diagram is represented in the form of activity graph which peaks are actions; arcs are qualitative transitions from one state to another [26, 28].

It can represent interrelations between the idea and visual results as well as describe internal structure of the represented objects and relation type. The diagram cannot indicate the data concerning temporary aspects of the whole system functioning. Class diagram is the further development of the conceptual model.

Class diagram is a certain graph which peaks are the components of "classificatory" type connected with different structural relations. Class diagram may also contain interfaces, packages, connections, and separate software packages. The diagram means static structural model of the system being designed. However, it depends upon the changes in space and time of all the processes being modeled. Class diagram consists of numerous components demonstrating in their totality the declarative knowledge on the area under study. The knowledge is interpreted in basic concepts of UML language. In this context, separate diagram components may form the packages to represent more general model. If class diagram is the part of some package, then its components should correspond to the package components including possible references to the components of other packages.

In general case, package of a static structural model may be represented in the form of one or several class diagrams. Certain representation is decomposed into separate diagrams as a matter of convenience as well as for graphical visualization of structural relations of a visual area. In this context, diagram components correspond to the components of a static semantic model. In turn, a system model should be conformed to the internal class structure being described in UML language.

Class in UML language is to determine certain number of objects having similar structure, behavior, and relations with the objects of other classes. Graphically, the class is shown in the form of a square which can be divided additionally into sections by horizontal lines. The sections may contain the name of class, attributes (changeable data), and operations (methods to achieve the result).

Process of the class diagram development is in the center of object-oriented modeling of complex systems. Ability to select the classes properly as well as to find relations between them is often crucial both for programming and productivity of the programs execution. As practice shows, each programmer wants to use personal experience while developing new projects. It is stipulated by the desire to reduce new task into the partially completed ones to have the possibility of applying the tested fragments of a program code and separate constituents of the component library.

Such an approach makes it possible to reduce considerably the period of project implementation; however, it is reasonable only in case when new project does not differ too much from the previous ones in terms of its concept and technology.

After the class diagram development, modeling process may continue in two ways. On the one hand, if system behavior is trivial, then one can start developing cooperation diagram and component diagram. In terms of complex dynamic systems, the behavior becomes the essential aspect of their functioning. Behavior is the specified consequently while developing diagrams of state, situation change, and activity during the implementation of technological solutions.

The author has made an attempt to systematize into a single system a computer-aided design for simulation representation of a mine as a single model consisting of various class interactions according to certain clear scheme within the class diagram of functional design system (Fig. 1).

Class program consists of the functionals determining the mathematical mechanism to be involved into the modeling and the sequence of the mechanism involvement.

CCadApplication is the collection of the required documents (cross sections of mine workings and lithological difference of rock which a user deals with) and their processing: adding the necessary clarifications, deleting, and saving the documents. The class provides the connection with graphic interface of the program: it complements the toolbar with graphic element objects (lines, texts etc.) and commands (switching on/off 3D object demonstration).

CCadDocument is the collection of CcadShape objects (additional graphic elements: lines, splines, texts, coordinate grid, contact planes, representation of mine workings) and the collection handling: adding, deleting, clear line-tracing, object searching etc.).

CCadShape is the basic class to describe the objects behavior in the document. The essence and the objective of the class are as follows:

– processing the events performed by means of the control systems (touchpad, mouse, keyboard);

– clear line-tracing of the object;

– initializing the basic parameters (colour, lint thickness; object orientation both in space and in Cartesian reference system);

– saving the parameters restoring with the help of CCadParameters class. It is used to save the parameters of all the objects in the unified format. Moreover, it helps save data in a file and organize incorrect action cancelling; and

– operations with the object: moving, testing the conditions (a point in the document belongs to the object; square area of the document contains the object itself).

CCadDrawer is the clear line-tracing of the corresponding detalization (set of functions to perform graphic drawing); it is used by CCdShape objects and represents following object types either in display or printed form:

– Line (thickness, colour, type (solid, dashed);

– Spline (thickness, colour, type);

– Point (mostly to indicate the area of object editing);

– Text (font, size, inclination angle, colour);

– Rectangle, triangle, circle etc. (object of the preset shape).
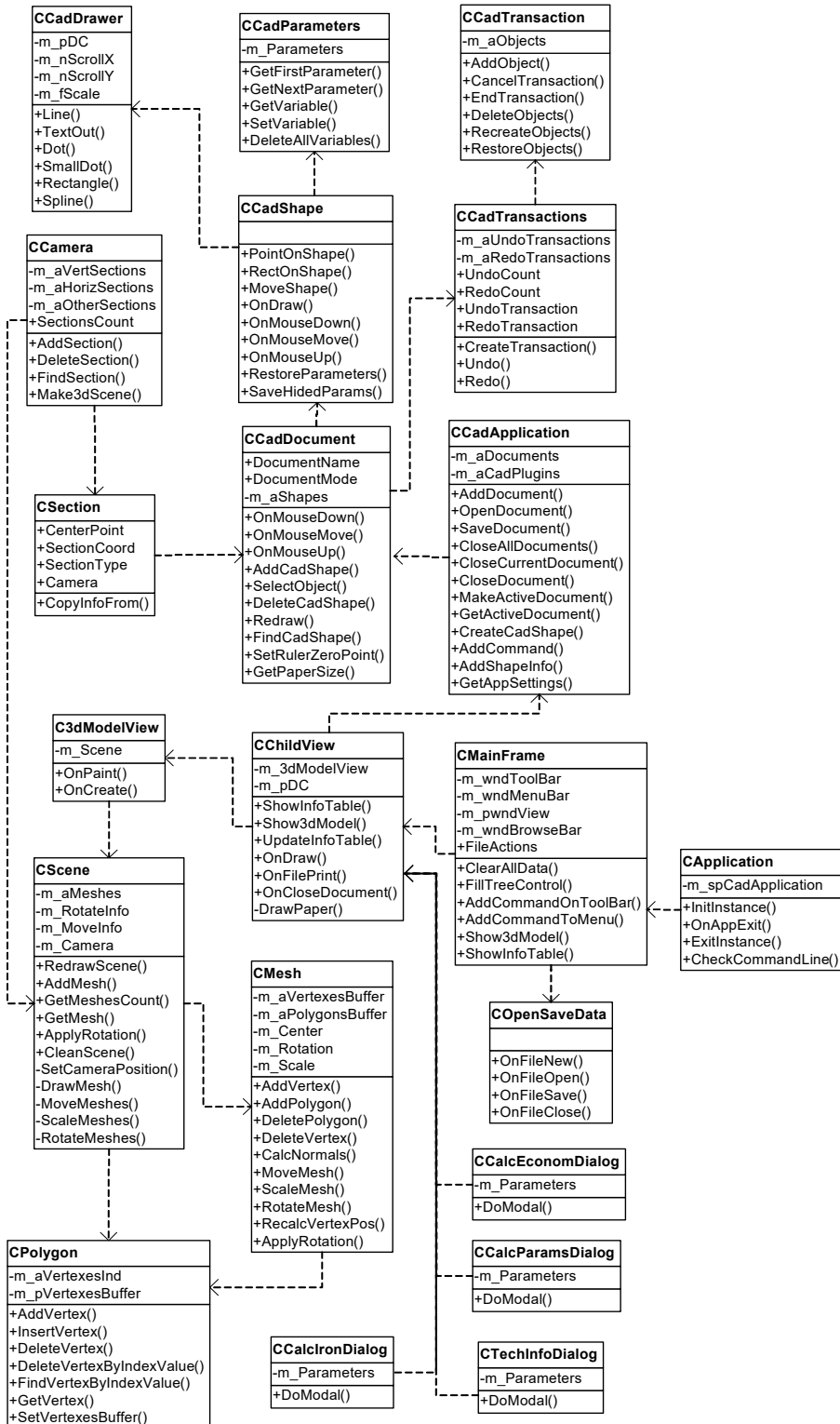
Fig. 1. Class diagram of the functional design system.

CCadParameters are the data storing the CCadShape objects. The data are stored in the form of pairs of rows called "variable name", "value", and "visible/invisible". If the variable is "visible", then its value may be changed in the property window.

CCamera is the collection of cross sections (a mine field site). Cross section objects may be deleted, added, corrected, and searched for. Similarly, 3D model of mine field parts is built in this class.

CSections is the cross section description (section types (vertical/horizontal), vertical coordinates, horizontal coordinates).

CCadTransaction, CCadTransactions store the object changes; they are also used to delete incorrect actions. Before any CcadShape graphic object changes, sample of CCadTransaction and copies of CCadShape object state in the form of CCadParameters sample are created.

C3dModelView is graphic elements for 3D mine representation. It initializes OPENGZ library, processes window messages of a mouse, and transmit them to the CScene sample.

SCscene is the class of the operation with 3D objects. It contains the collection of 3D objects (CMesh), position of a viewing point (a video-camera principle) within the "space - time" system. It implements clear line-tracing of all the objects, their selection, change in position and rotation as well as change in position of the point itself.

CMesh is the description of 3D object, movement operation, and rotation. It contains collection of polygons (CPolygon) and collection of points (CVertex). Together they gives the good tool for the visualization of processes.

CPolygon is the description of polygon (elementary 3D object). It contains the array of indices and points of spatial representation of different simulation objects located in CMesh.

CLine, CText, CSpline are basic objects of the document inherited from CCadShape. They are used to process and display both text and graphic information. In addition, their function is to visualize final information and demonstrate it to a user in the aesthetic and accessible form.

CSectionCoord is graphic representation of the document grid mesh. 3D model is used to determine the corresponding cross sections of all the modeled objects and to represent them in the form of lines.

CIronContour determines the design limits. In this case, there are two levels of representing the simulation representation limits: mineral contour within the whole mine and within the separate extraction site. The class is also responsible for the representation of rock difference within the vertical plane – limits for roof and floor rocks simulation.

CSurveyTraverse is the representation of man-made objects – all the underground and surface structures in reliance on their shapes and corresponding geometry.

COpenSaveData is operation and command class. It provides the opening and storing of the file containing the whole information. The class is responsible for the control of all the developed information.

CTechInfoDialog contains the information concerning databases. Calculation results obtained by other software products also act as the input information apart from the statistic data. In our case, these are the data from the assessment of geomechanical situation within a certain extraction site.

CCalcEconomDialog is the class of economic effect calculation; it is responsible for economic expediency of the implementation. The available principles to assess the efficiency of implementing new equipment and technology under certain mining and technical conditions are used as a mathematical mechanism.

CCalcIronDialog is responsible for rock pressure calculation; it represents geomechanical situation of the areas under study. In this case, Flac 5.01 software is applied; the software product uses finite difference mode in terms of elastic-plastic representation of the rock mass. The obtained results are compatible with CTechInfoDialog class.

CcalcParamsDialog is the calculation of technological parameters. It is a final stage of software operation and aimed at selecting rational use of high-load coal extraction relying upon technical provision of mechanical coal breaking from a seam, its transportation, technological support of mining operations, operational safety, economic and environmental expediency. The developed class diagram of the functional design system is not the end product in the form of separate software package in the computer-programming language. It contains all the required constituents for simulation mine representation in terms of high-productive mining and near mining processes. The author has managed to implement only certain parts and combine them into the consistent simulation system.

4 Conclusions

Simulation is widespread in all engineering studies, mainly because it implements the principles of decomposition, abstraction and hierarchy [3]. Each model efficiency is determined by the results obtained in ordinary and unordinary conditions. Comparison of simulation results with the field data gives an opportunity to carry out the relevant software updating and adjustments.

Simulation modeling is quite efficient, flexible, and dynamic method to represent complex systems; the method is the integral part of representation of complex mining production processes. It is based on a stable theoretical basis and at the same time gives the programmer a certain degree of self-expression will.

Development of a mine simulation model is not aimed at the development of a final product in the form of software package; its objective is to build up clear system of its implementation including all the mathematical algorithms used for calculations. Such models are also necessary in the secondary extraction of raw materials from dumps, recycling of mine wastes or purification of mine and wastewater.

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