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Object-oriented modeling for three-dimensional multi-block systems

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A B S T R A C T

This paper presents an object-oriented computer model for three-dimensional multi-block systems based on the object-oriented programming (OOP) technique. The intricate structures of rock systems are deciphered by implementing an object-oriented analysis (OOA), and a universal class library is developed using an object-oriented design (OOD). The geometries of a multi-block system are created by cutting a computational domain into element-blocks and then combining the element-blocks into complex-blocks (convex or concave). The established multi-block system model would be available for various discontinuum-based methods. A computer program, BLKLAB, is developed based on the proposed method, and a case study is performed on a large-scale, underground, water-tight oil depot.

1. Introduction

Rock masses, such as the Earth's outer solid layer, are undoubtedly significant for underground constructions; rock masses are also an extremely complex geologic media born with numerous geologic planes, which cut rock masses into block assemblies (multi-block systems). Unlike crushed rock or intact (or almost intact) rock, blocky rock masses cannot be reasonably simplified as a continuum; conversely, its behavior is mainly dominated by the geometrical distribution and physical properties of the various discontinuities [1–4]. The discontinuities, especially faults and large joints, have a considerable effect on the stability of the rock systems and the safety of underground facilities. Therefore, a thorough discontinuous analysis requires a realistic computer model that should explicitly reflect in situ rock systems, including their complete internal structures, intricate topological information and complicated geological data.

The structurally controlled behavior of rock media, caused by the occurrence of discontinuities, is three-dimensional. Therefore, a three-dimensional description of rock mass systems is required. Initial research on block polyhedral identification was conducted by Warburton [5] and Heliot [6]; however, only convex blocks formed by idealized infinite discontinuities can be detected using their algorithms. Over the past two decades, many methods have been proposed or improved to construct three-dimensional rock system models with complex geometries. In general, all these methods can be classified into one of two categories: the block tracing approach and the block assembling approach.

- The block tracing approach (BTA) [7–12] is based on the theory of topology or directed graphs. For example, Ikegawa and Hudson [8] used the directed body concept to identify both convex and concave blocks. Jing [9] proposed a block tracing method based on the basic principles of combinatorial topology (e.g., boundary chain operations and the Euler–Poincáre formula of polyhedra). Elmouttie et al. [11,12] developed a robust algorithm for the accurate modeling of polyhedral rock mass structures with multiple curved, finite persistent discontinuities and the realistic simulation of underground excavations with arbitrary configurations; this algorithm extends BTA with important improvements to robustness and efficiency. The accuracy, robustness and computational complexity of the polyhedral modeling algorithm have also been systematically studied [11].
- The block assembling approach (BAA) [13–15] is based on the concepts of basic geometrical theory and the technique of polyhedral combination. The procedures and methods in this category can be summarized into two steps: preparing the convex elemental blocks and combining the elemental blocks to construct complex blocks. Because the geometry of a convex block can be uniquely and easily determined by its vertices, the BAA can avoid the complicated topological detection of directed edges, loops and polyhedra in the BTA (a detailed description is presented in Appendix A). In this category, the method to

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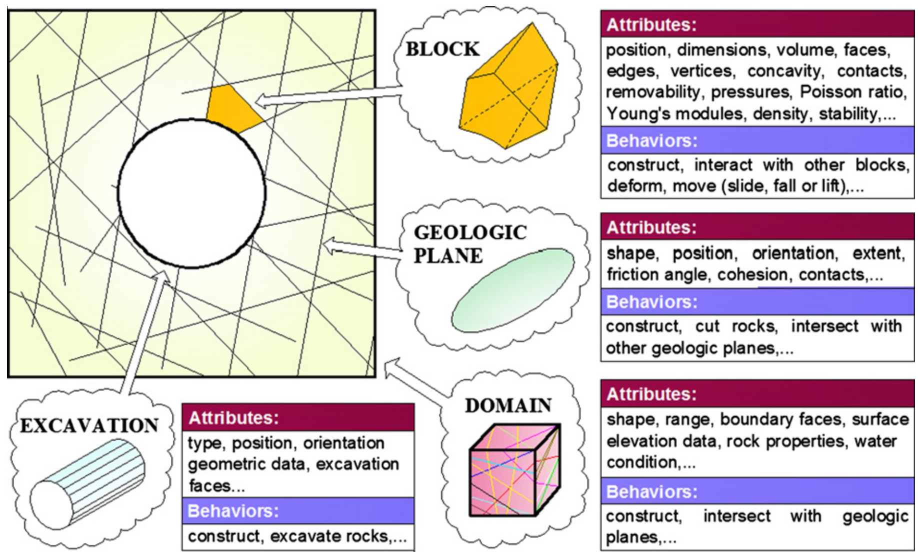

Fig. 1. Objects involved in a typical multi-block system.

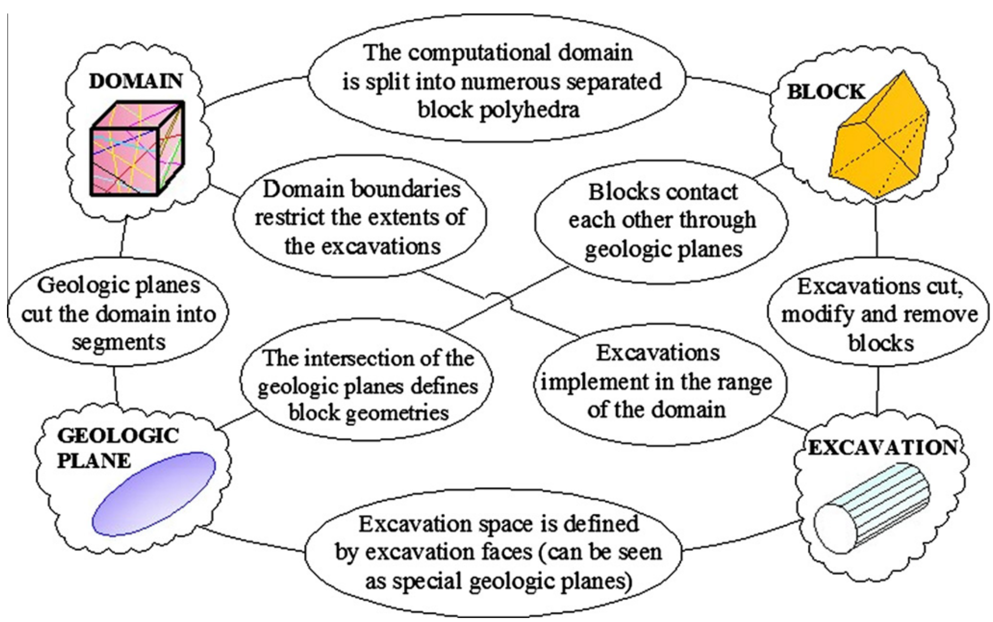

Fig. 2. Correlation networks of objects in multi-block systems.

create convex elemental blocks varies. Zhang et al. [13] recommended that elemental blocks can be produced by modifying the finite elements that are generated by existing finite element software. However, more cutting and combining operations will be implemented because the generation of initial finite elements does not consider the distribution of geologic planes. Yu et al. [14] introduced a generalized procedure by cutting domains into convex polyhedra using infinite discontinuities and then combining the convex polyhedra into complex blocks by restoring discontinuities into finite discs, but no systematic data structures or detailed modeling algorithms were presented to accomplish the construction and visualization of large-scale rock systems.

This paper proposes a method of constructing the geometries of multi-block systems by identifying element-blocks and then combining those components to construct arbitrary blocks. This method can be classified into the BAA and it can construct and visualize any complex geometry of natural rock masses split by different types of discontinuities. Furthermore, a data structure framework for integrating and organizing the rock mass information is developed based on the object-oriented programming (OOP) technique due to its superior software development capability [16,17]. The research objectives are as follows:

(1) Deciphering the intricate structures of the rock systems by performing object-oriented analysis (OOA) and then designing a scientific data structure framework to organize the massive rock system information by implementing object-oriented design (OOD).
(2) Generating diverse geologic planes including finite and infinite joints, deterministic and stochastic fractures, and large faults with intercalations.