The use of parametric modeling as the geological description of the surrounding rocks in the workings.

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Abstract. The use of parametric modeling, similar to BIM (Building Information Model) technology, widely used now in the building construction industry, and very interesting to use this approach in documenting and modeling underground space.

Unlike construction sites, not reinforced tunnels and underground workings have a very large specific associated with the properties of the surrounding rocks, which are described by specific technical and physical parameters, taking into account their resistance over a long period while using them for the purpose of extracting a useful fossil.

Geotechnical modules built into Autodesk products are designed to solve specific problems in the construction of concrete tunnels and other facilities related to the bowels. A geological model in that module is a collection of AutoCAD® Civil 3D® triangulation models (planar surfaces) that display the top and bottom of geological layers, indicating the thickness of the geological layer and tracing the boundaries of the surfaces. Solid-state models are formed only at the locations of geological wells, illustrating their composition using conditional 3D AutoCAD® bodies constructed in accordance with good patterns.

Authors of this presentation propose the primitive families for the description of the geological and structural composition of rocks around the not reinforced tunnels are being developed for the Autodesk Civil 3D and Revit program.

At the same time the use of the FreeCAD program, which supports the exchange of parametric data in the IFC (Industrial Foundation Classes) format, can be also very promising, which means that the primitives developed in this program can be used in the Autodesk software too.

Parametric models of rock in the workings can play the role of the information model while calculating the stress, deformations, heat distribution and other physical fields for different technical applications. As an Open Source software with sufficiently developed tools for modeling and parametric description of models based on information modeling, with a certain adaptation, FreeCAD program can be used for this tasks, it can also be used as the basis for creating a unified information system for underground laboratories at different scale of accuracy needed for any calculations.

Given that the FreeCAD program allows you to export information model data to all programs that support the formats of such models using the Industrial Foundation Classes (IFC), the main primitives and material libraries were used on the basis of this program.

Main Idea

As a basic basis for creating the scale of the model under discussion, we use the most common hypothesis in Russian practice of Professor M.M. Protodyakonova [1]. According to this hypothesis, the rock exerts pressure on the roof of the mine by its weight in the volume of the so-called set of pressure, within which rock collapse is possible. The pressure vault has the following dimensions: height h1 and width 2b1.

Therefore, in the future, the length of fractures and other inhomogeneities in the proposed model will be limited by the arch curve. Moreover, it is practically impossible to extend the extension of fractures to a great depth without additional information on their parameters, and hence additional drilling.

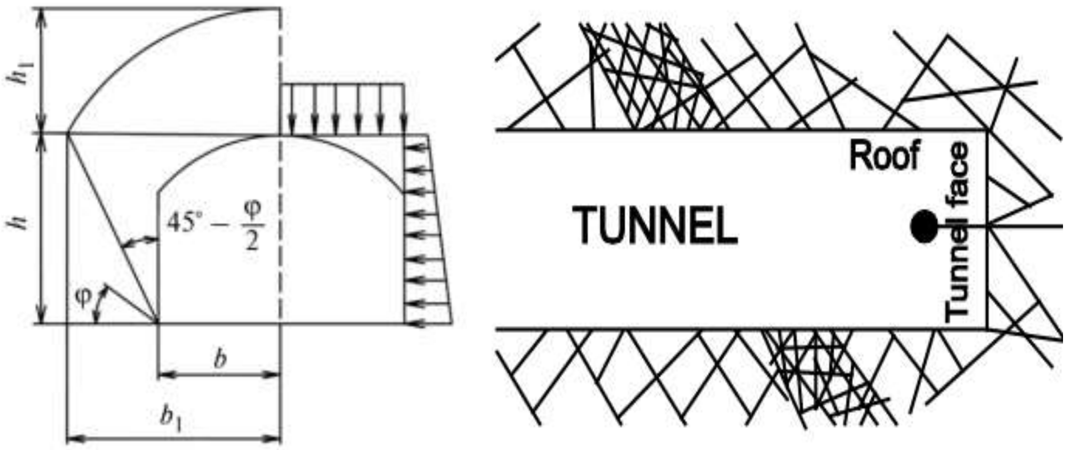

Figure 1. Rock pressure pattern according to Protodyakonov [1] and fracture diagram in the surrounding rock [2].

Figure 2. The wall of the underground mine. The wall material is marble, the dark vein is amphibolite.

The parametric model of the underground mining itself, in fact, is the "extraction" of rock from the massif. This process can be modeled using modern parametric modeling programs. We will use the very famous FreeCAD program, which is dynamically developing and compatible with modern design and project software, which has the advantage that, with all its power, it develops in the form of a freely distributed program.

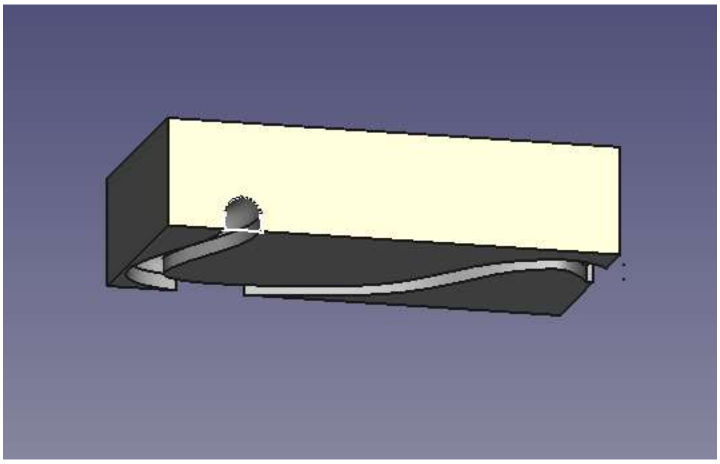

Figure 3. Parametric simplified underground mining model

Developments can be documented and modeled by various methods, including the use of various laser TSL scanners or by photogrammetry. The resulting models in the form of a point cloud or polygonal models can be embedded in the array model.

Basic primitives of the parametric model of the massif

The solution of the problem of modeling geological parametric objects can be carried out on the example of a three-dimensional section of the mountain massif, as shown in the figure below. Despite the primitive approach, all of these conclusions can be applied to large models.

As a modeling tool, we use the FreeCAD program, which is compatible with AutoCAD family programs through export in the Industrial Foundation Classes (IFC) format.

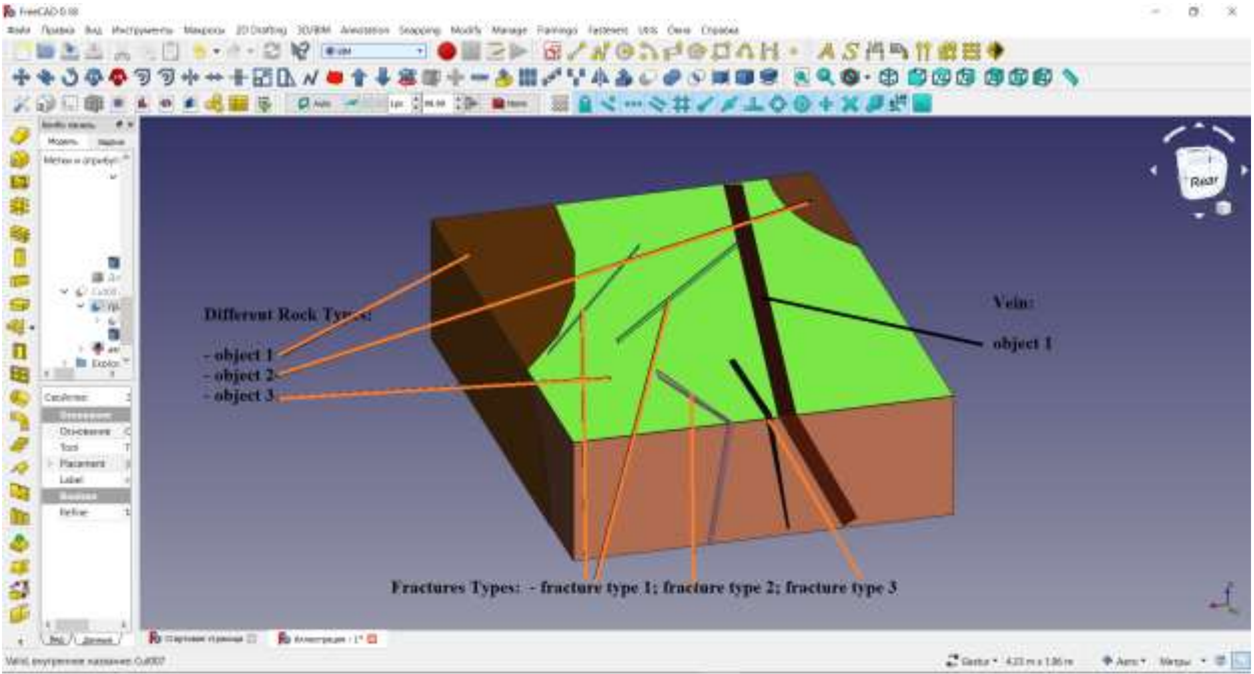

Figure 4. Parametric model of a section of a mountain massif represented by geological bodies (objects), fractures of various types and mineral veins.

Three objects were chosen as the basic parametric geological primitives: a fracture, a rock, a testing point. It should be noted that many fractures can be qualified as "healed", that is, filled with mineral masses that have good adhesion to the fracture faces, and the contact between rocks of various types may contain a fracture. These cases will be discussed below.

Fracture. There are many definitions of fractures: "Fracture is an extreme defect representing regions with completely broken interatomic bonds (fracture faces) and partially broken interatomic bonds (fracture tip). The coastal interface is called the crack front". In the classical version, a fracture is understood to mean the space between the sides of the gap filled with a physical substance (air, water, mineral aggregate) characterized by the coordinates of the center of the crack, elements of occurrence, surface roughness and characteristics of the aggregate.

A new paradigm in the proposed material, in connection with this, we propose the idea of a fracture as an independent geological object that coincides in shape with a discontinuity in a solid that inherits its shape, occurrence elements and surface roughness of fracture faces, characterized by the physical and mechanical properties of the filler and non-zero dimension.

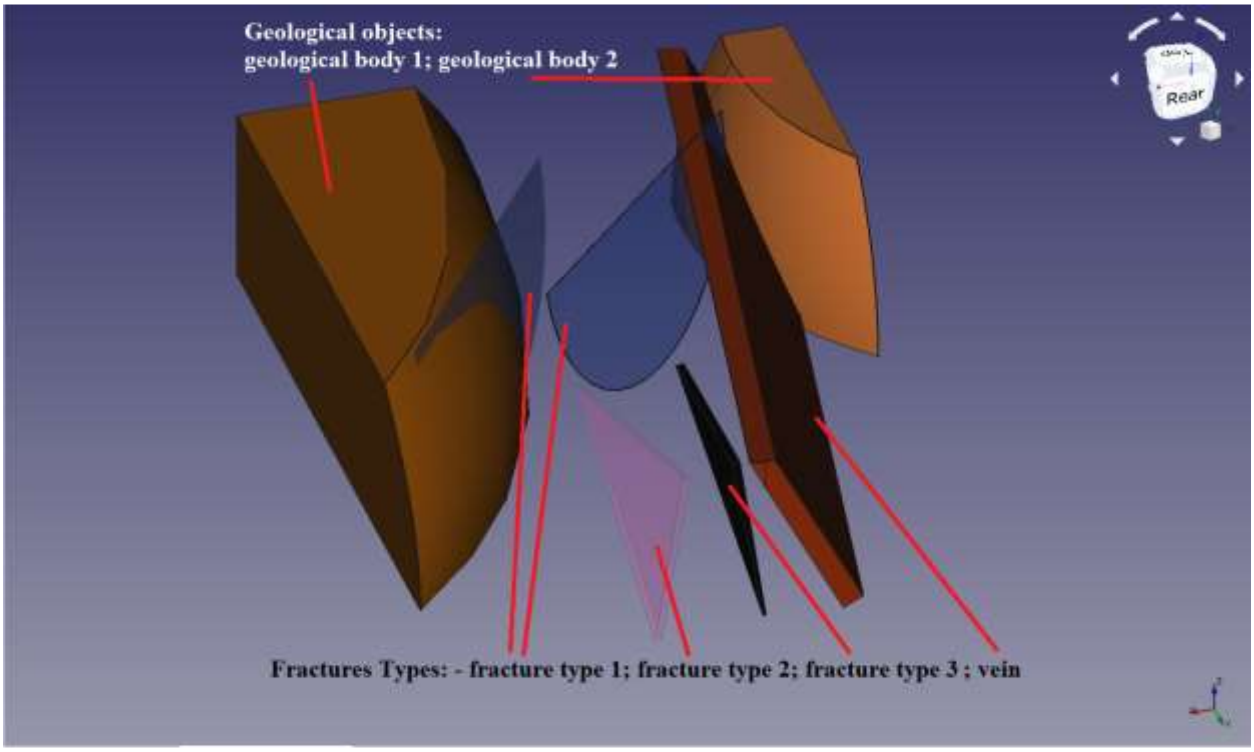

Figure 5 Fractures like objects in a rock

In the above figure, we can also attribute to the fractures a straight vein, which inherited an ancient fracture and is filled with mineral matter. Moreover, semantically, such a core does not differ in type from fractures of an open or filled type.

At first glance, such a decision is paradoxical. It looks like a “solid parametric donut hole model”. But, in fact, the model of the fracture, formulated in this way, will inherit roughness characteristics from the rock, that is, the boundary between the stone material and the fracture itself. Further, such a fracture will have a strong dependence on the contents of the fracture itself. Liquid, air, fracture width, bulk materials - all this affects the deformation processes in the massif and taking these parameters into account will only increase the accuracy of calculations in the behavior of the rock in force fields.

Our task is to develop new types of objects that can be used as initial primitives for digital models of geological bodies. If it is not a problem for parametric solids of a geological type, which are a separate type of rock, this is because the developed parametric units, such as building primitives, are already widely used in practice.

The difficulty arises only with the prototyping of fractures, like gaps in the material. For geological purposes, this is compounded by the fact that such fractures can have a complex structure both in shape and content. In this work, fractures are separate objects that are perceived as individualized quasi-bodies of various types. Moreover, they, having appeared in the rock due to various kinds of geological processes, are an integral part of this rock. For modeling purposes, this approach will be quite appropriate, because it makes it possible to take into account the properties of these fractures in the future when performing various kinds of calculations in FEM systems - finite element analysis, DEM - discrete element analysis, and other similar programs.

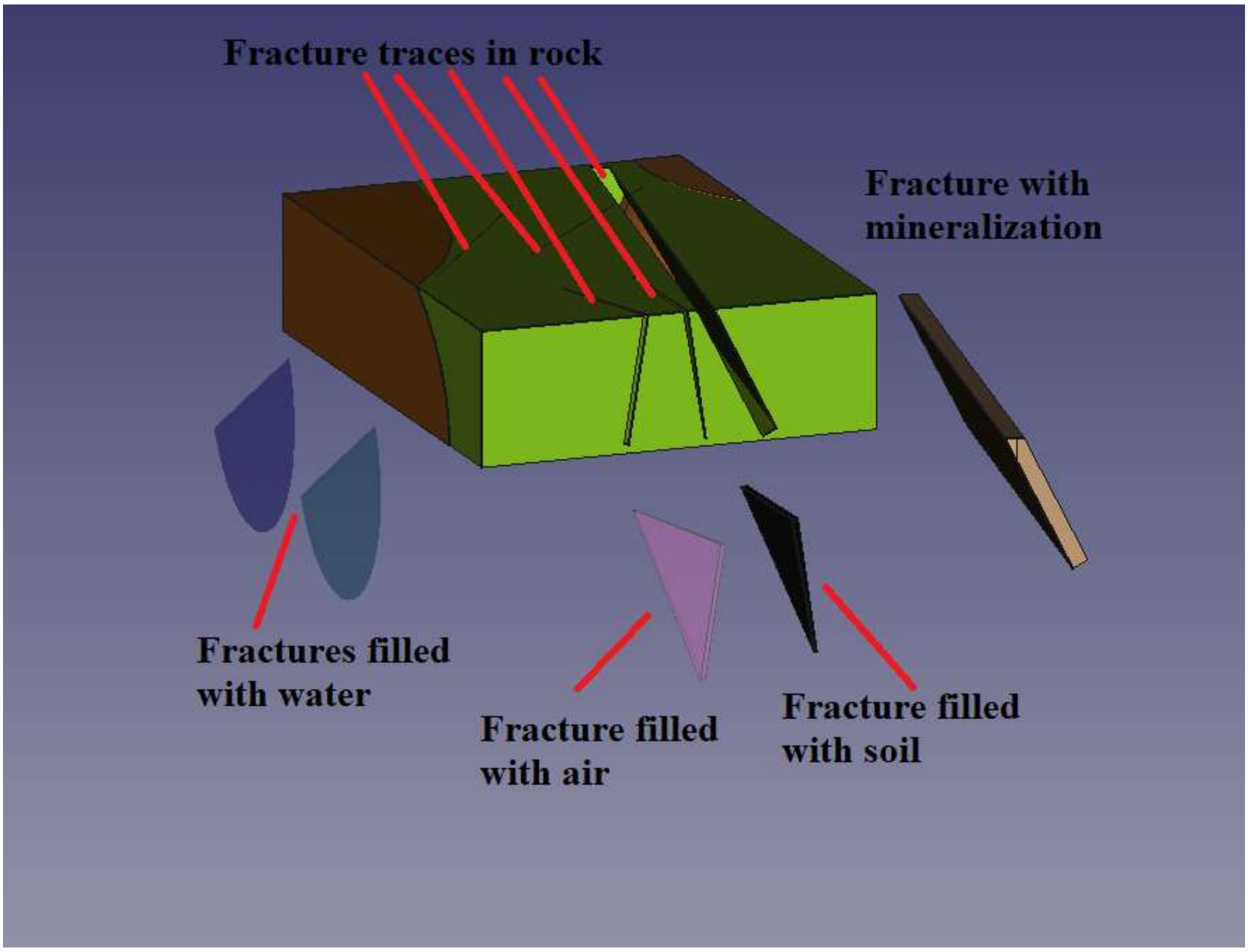

Figure 6. Fractures as independent geological objects

The presented types of fractures and their traces in the rock can be classified by their filler. The shape, as is currently accepted for such objects, in such cases is limited to a semicircle, rectangle, or other flat figure of the size that we can consider adequate for this outcrop. A fracture filled with air will be invisible in the picture, so it was slightly tinted with pink color for identification. A cured fracture of a small (reasonable) power of a rectilinear size can be interpreted as a fracture. With much larger sizes and irregular shapes, these bodies can be attributed to geological objects.

The proposed types of fractures are classified according to the placeholder filler and can be divided into the following groups:

- air fractures, fractures having an air gap and upon visual inspection are characterized as empty;

- fractures filled with liquid - fractures filled with any liquid (water, oil);

- fractures filled with loose soils - fractures that are filled with loose mineral formations (sands, clays, gravel mixtures, etc.);

- mineralized fractures, fractures that were healed in the course of previous geological processes and now form a single mass with host rocks.

Also, these fractures are characterized by thickness (width), filler properties, visible length, strike and dip angles. In a rock, a fracture is most often visible in one plane, although occasionally we can observe it in two or more planes.

The illustration above is an interpretation of the concept - “a fracture as an independent geological object”. Below are various geometric types of fractures with their passport data.

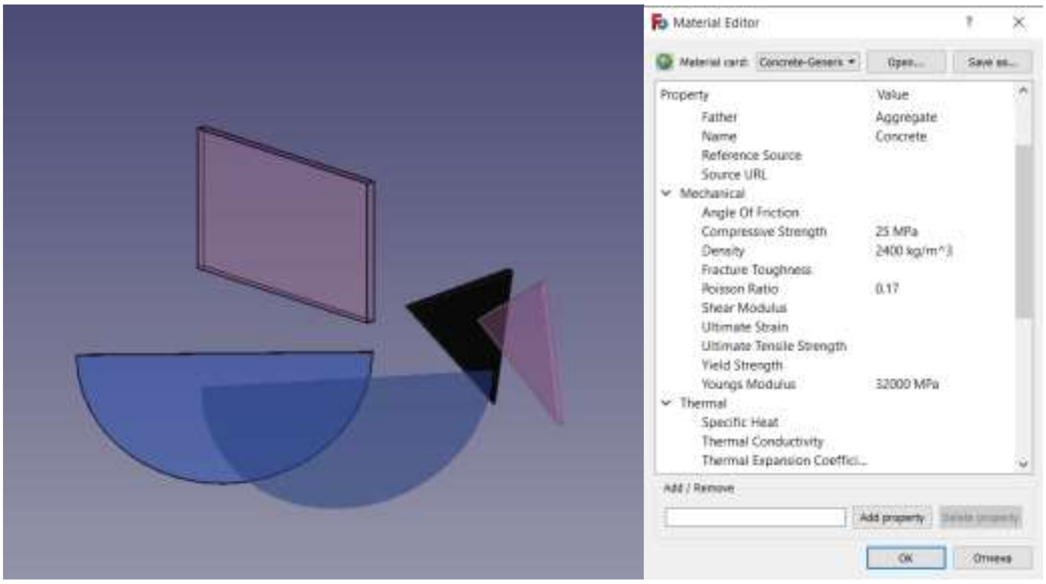

Figure 7. Fractures and material editor window. Concrete is used as aggregate.

Each object in parametric modeling is characterized not only by size and shape, but also by their physical parameters. The FreeCAD editor allows you to organize this for each object, forming a library of properties of the simulated array. Each such parameter can later be used for specific calculations and calculations. For the example in the figure above, as a characteristic of the fracture aggregate, the characteristics of ordinary concrete were used, which can hypothetically fill any fracture.

A geological object is taken in the form of bodies of various shapes corresponding to a specific mineralogical composition and therefore characterized in the form of a specific geological formation. Such bodies, as necessary, include bodies of other breeds of various sizes, shapes and various mineral composition. Loose bodies in steady state can be interpreted as geological objects. The geological body is characterized by the uniformity (heterogeneity) of the mineral composition, anisotropy elements and the configuration of physical fields.

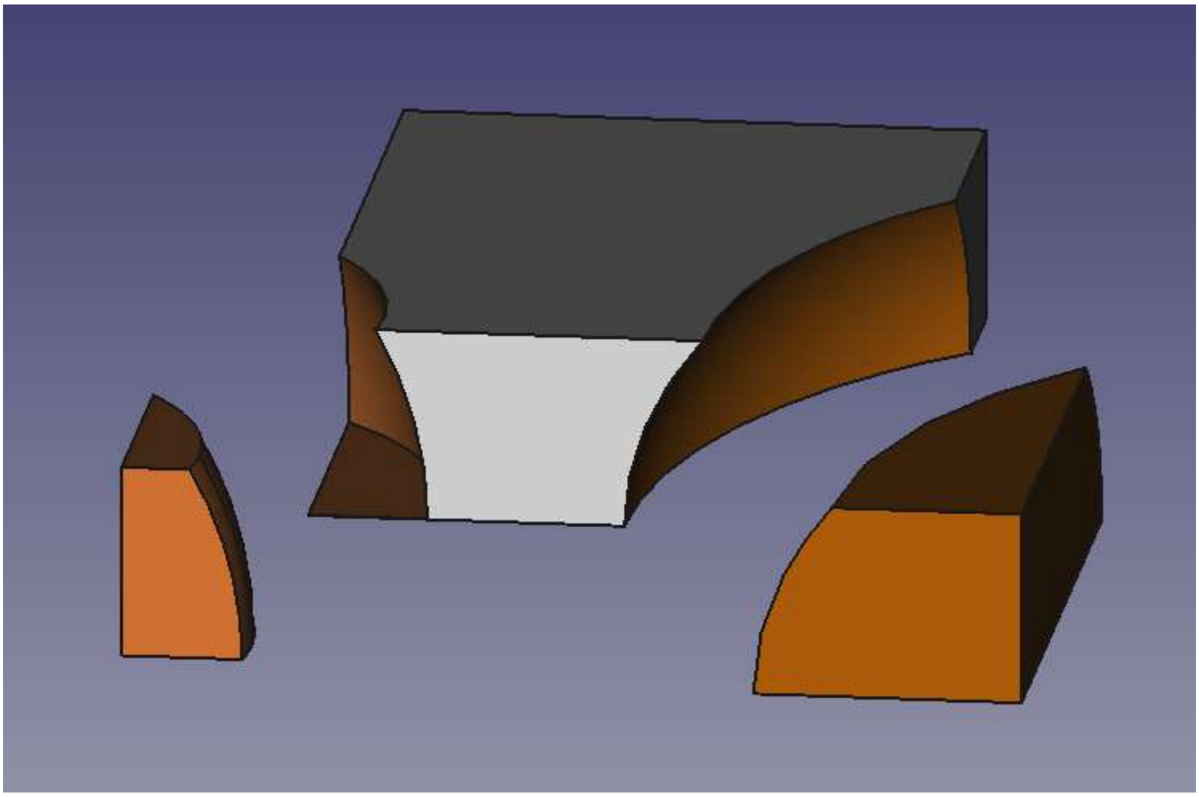

Figure 8. Parametric geological bodies

The shape, size and characteristics of parametric geological objects are stored in programs like FreeCAD in digital form. Each such object is solid-state, which makes it possible to characterize such a volume with relevant digital information about the quality of the geological body, mineral composition, conditions of origin, physical and physico-mechanical properties, and other relevant properties.

Point of testing. This is the place of sampling a certain sample volume or measuring geological and geophysical characteristics. It is characterized by the size of the volume or mass and its geometric center is located in the center of this volume. Such points can indicate both physical measurements, where the size of the point can vary in any reasonable range that allows them to be visualized, and have certain sizes, which are determined by the size of the sample that was taken at this place. Each such sample, ultimately, must be characterized in the process of studying the selected sample, the results will be a passport of this point.

The shape of the sampling point depends on the sampling methods used - a cylindrical one will characterize a core sample, a rectangular one will characterize an ore sample, and a ball will measure a physical parameter in a particular place.

Samples of parametric objects of this type are shown in the figure below. The spatial characteristic of such objects will be their coordinates in the model used.

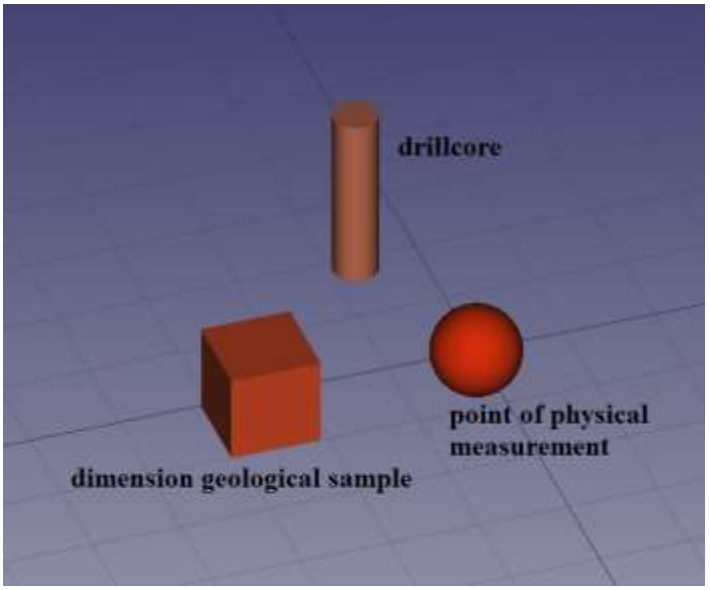

Figure 9. Parametric objects of the type of testing point

Parametric geological objects can be created in FreeCAD both directly in the program and transferred from other programs in the form of shape objects.

The position of objects in the geological model can be described by parameters, as shown below. Transfer of ready-made planar models can be carried out according to characteristic parameters.

Fracture: Point in the middle of the fracture.

- Coordinate of point 1- X1, Y1, Y2

- strike azimuth

- Fall azimuth

- fracture width

Geological body: Characteristic points on the surface of a planar model.

- Coordinates of point 1 - X1, Y1, Y2

- Coordinates of point 2 - X2, Y2, Y2

- Coordinates of point 3 - X3, Y3, Y3

Place of sampling: Point in the model.

- Point 1 coordinates

Creation of new objects in the FreeCAD environment can be carried out according to the same algorithms as in other geological programs.

Solid modeling is not only a technology for visualizing real geological objects, but also the ability to perform various manipulations with them in three-dimensional space, similar to how it is used in physical modeling of processes.

Currently, the representation of a solid in design practice is based on BREP, a method of representing shapes using borders, where a solid is a combination of interconnected surface elements - the boundaries between the body and the surrounding space.

Conclusion

The main purpose of this presentation is to discuss the possibilities of modeling rocks as parametric 3D objects, taking into account all the features of their structure.

Fractures play a huge role in the formation of rock mass properties at different scales. They affect the strength properties of the array, the speed of passage of elastic waves. Moreover, even knowing the parameters of the rock, we cannot adequately assess the contribution of the fracture to the formation of the mechanical, acoustic, seismic properties of geological bodies due to many uncertainties.

The selection of fractures in a separate class of objects during solid modeling of rocks can move the solution to this problem. Or not?

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