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Development of a tool for interactive detailing of areas of objects for the strength modeling system

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Introduction

The development of technological progress makes increased demands on the strength properties of structural elements of buildings and structures, machines and mechanisms, and a decrease in their material consumption. This leads to the need for effective use of existing and creation of new methods of solid mechanics and the training of new highly qualified specialists.
One of the most important tasks in the field of deformable body mechanics is the representation of an existing CAD model in the form of a finite element mesh. Such a transformation will allow for the final calculations and optimization of the mathematical parameters of the object and will allow solving the following problems:

- Preservation of all geometric features of a complex object in its model.
- Ability to make changes of any scale to every part of the model.
- Support for complex operations with the object: local rescaling of big and small details, optimization of parameters.
- Elimination of loss of information about the properties of objects.

Our work aims to find the optimal way to solve these and other related problems.

Related work

Although various popular solutions already exist, both open-source (Freecad, Salome) and commercial (Comsol, Ansys [1, 2]), they nevertheless have their drawbacks. In particular, to make the user experience as easy as possible, integration with an intuitive visual interface is required. This approach will provide interactivity, as well as the speed of interaction and execution of operations. Its implementation will increase the speed and productivity of work, as well as reduce the requirements for the necessary user skills.

Problem definition

Various existing methods of numerical modelling are based on testing the technology's operability on separate boundary value problems and do not allow the transition from the description of the algorithm to its immediate application by end-users. Our goal is to create an environment suitable for easily integrating custom calculation methods into the underlying system we have implemented. At the same time, an important task is to support local scaling.

System description

We believe that the most optimal solution for the described problems is an implementation in the form of a computer-aided design system, modelling and processing of objects. To improve efficiency, the web service format was chosen [3, 4]. At this stage, the following prototype system was developed in Python:

- The Jupyter framework, as well as the GMSH and VTK utilities, were chosen as the basis for the interface visualization;
- To implement the automated design of 3D models, tools of the PythonOCC, VTKjs libraries were used;
- The main functionality of numerical calculations was performed using the FEniCS library;
- Containerization is done using Docker functionality.

The proposed solution made it possible to introduce a step for interactive adjustment of the local mesh resolution between the step of modelling the object and its division into finite elements.
Additionally, it should be noted that the system supports topological optimization of the object - it allows you to automatically optimize the model for several user-selected characteristics, and then compare it with the original one.
The algorithm described in the presented work allows the creation of rather complex objects using only a mathematical description of the various parts. This gives us many opportunities to fine-tune the characteristics of the processed object. At the same time, the implementation of tools for managing the local mesh resolution will allow users to integrate their modern numerical methods, such as XFEM and GFEM, the use of which is not available in existing modelling packages.

References

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Summary

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