Title:

APPLICATION OF TOPOLOGY OPTIMISATION FOR AN ARCHITECTURAL FORM-FINDING PROCESS. ADAPTATION OF ENGINEERING METHODS FOR ARCHITECTURE PURPOSE

Abstract:

The development of digital technologies and the expansion of information technology have contributed to the spread of digital design tools among architects. The interdisciplinary nature of architectural works and the need for a comprehensive approach to the problem make architecture react to the development of digital technologies extremely strongly. The digital medium has contributed to the creation of new dependencies and conditions between the design process, engineering and implementation. Architecture as a broad discipline in which the form closely cooperates with engineering, extended by additional design and analytical methods, gains additional substantive and aesthetic value.

One of the most important numerical methods, which is currently the primary tool for computer-aided scientific research and engineering analysis is the finite element method (FEM). It is a method of solving partial differential equations found in equilibrium equations in static problems. It is characterized by a very wide range of applications and high popularity. It allows testing the structure of a building in terms of its deformations, displacements or deformations in connection with the loads acting on it. It plays a basic role of the analytical module for the material distribution process based on topology optimization algorithms. It allows for an efficient distribution of the construction material in a certain design space under the assumed load and support conditions, in order to obtain the most durable and light structures possible. Both methods, supporting each other, are essential tools for research and exploration of architectural structures presented in this work. Actuated research problems involves three areas of knowledge: architecture, civil engineering, and computer science. The main purpose of the work is to research by using innovative tools, how parametric design supported by numerical methods, can influence the process of searching for optimized architectural forms.

The new tool that implements the principles of topological optimization, adapted to the workshop of a modern architect has been created. The tOpos program is an attempt to use numerical tools and algorithms to search for architectural forms, based on a parametric design program such as Grasshopper3D. In order to maximally speed up the process of generating the form, the possibilities offered by the technology of calculating on GPUs called GPGPU were used. In the case of the tOpos project, Nvidia's CUDA technology was chosen.

The research was carried out on the schematic forms of buildings for which various initial conditions and restrictions were applied. The results from all series of tests clearly show that the obtained structures can successfully fulfill the role of architectural form or be an inspiration for it. Created software gives unlimited possibilities in the process of creation of forms. Each new boundary conditions, the shape of the design space, whether the restrictions, will result in generating a new form, adapted to the requirements set by the user. The implementation of the form-forming principles of topological optimization using the idea of parametric design enables designers and architects to look for structures and inspirations for architectural forms in a simplified and intuitive way. The use of numerical methods as a base for generating forms has resulted in receiving interesting structures rich in interesting detail, which have gained additional value. Final forms are not composed from readymade architectural solutions, but it is a unique answer to a given problem.