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Review

Topology optimization aided structural design: Interpretation, computational aspects and 3D printing

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Abstract

Construction industry has a major impact on the environment that we spend most of our life. Therefore, it is important that the outcome of architectural intuition performs well and complies with the design requirements. Architects usually describe as “optimal design” their choice among a rather limited set of design alternatives, dictated by their experience and intuition. However, modern design of structures requires accounting for a great number of criteria derived from multiple disciplines, often of conflicting nature. Such criteria derived from structural engineering, eco-design, bioclimatic and acoustic performance. The resulting vast number of alternatives enhances the need for computer-aided architecture in order to increase the possibility of arriving at a more preferable solution. Therefore, the incorporation of smart, automatic tools in the design process, able to further guide designer’s intuition becomes even more indispensable. The principal aim of this study is to present possibilities to integrate automatic computational techniques related to topology optimization in the phase of intuition of civil structures as part

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of computer aided architectural design. In this direction, different aspects of a new computer aided architectural era related to the interpretation of the optimized designs, difficulties resulted from the increased computational effort and 3D printing capabilities are covered here in.

Keywords: Computational Mathematics, Industrial Engineering, Computer Science, Civil Engineering, Structural Engineering

1. Introduction

Over the years engineers continuously strive to improve the efficiency of constructions concerning safety, economy and recently sustainability during service life. Among others, the progress in building engineering is achieved through formulation of new design and assessment procedures with respect to structural, energy and environmental performance that usually require increased computing power. This has in turn resulted in two major paths of innovation: enhanced design algorithms and assessment methodologies on one hand and more powerful computer technologies on the other.

Development in analysis and design of structures has been invariantly associated with the formulation of more computationally expensive problems, since engineers can always formulate a problem that will provide a better solution, but requires more than the available computing power. Computational mechanics has played a key role in this process. Exploitation of the ever-increasing computing power requires the development of numerical techniques and tools, which has eventually allowed the simulation of complex multiphysics phenomena using in-depth approaches that have not been possible to be applied until today. Advanced computational methods for designing safe and economic structures have benefited from multidisciplinary approaches between computational mechanics and other fields. Actually, the next generation of computational tools and algorithms could have a profound impact and lead to groundbreaking developments in engineering practice. Driven by the dictum of the pioneer of the finite element method John Argyris "*The computer shapes the theory*" [1], structural engineering limitations imposed by large-scale computations can be dealt with. In modern times, civil engineers have to solve problems that are very demanding in computational power and runtime thus conventional methods fail to give a good approach. Today, due to the evolution of science, these conventional methods have been replaced by new computational tools that are cheaper, faster and their aim is to find the "best" through a range of safe options. This represents a major change of direction made in recent decades not only in the field of civil engineering but also in many other scientific domains.

Since 1970 structural optimization has been the subject of intensive research and several approaches for optimal design of structures have been advocated [2, 3, 4, 5,

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