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RESEARCH ARTICLE

The optimization of architectural shape based on Genetic Algorithm

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Abstract
Genetic Algorithm (GA) is widely adopted in optimization and the improvement of its optimization performance is attracting many researchers' attentions. In solving practical problems in the process of architectural design, the ways of converting design problems into mathematical models that can be addressed by GA are of great significance in achieving final optimal results. However, no such rule that can be applied to such conversion has been developed so far. In general, problems which can be addressed by GA can be divided into combinatorial problems and numerical problems. In this paper, by means of attempting to disintegrate a complicated architectural problem into combinatorial and numerical problems, the author discusses feasibility and practicality of solving these two types of problems simultaneously utilizing GA and discloses both advantages and disadvantages of GA by comparing with other algorithms.

1. Introduction

Genetic Algorithms have been introduced into architectural design field in general since a dozen years ago due to its special robustness and relatively simple implementation. Ever since then, they have been adopted in particular in optimizing the layouts of floor plans (Michalek et al., 2002) and site plans (Finucane et al., 2006), optimizing building façade designs(Caldas and Norford, 1999), optimizing forms of building structures (Papapavlou and Turner, 2009), and in some conceptual design (Soddu, 2005). However, unlike in other purely scientific research fields, problems in architectural designs are often mixed with social and esthetic

☆With reference to the shape optimization of Yangzhou South City-Gate Ruins Museum.

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factors which cannot be described by mathematical models. When a designer attempts to optimize design problems with the help of GA, facing such complexities inherent in architectural designs, he or she has to convert specific problems into combinatorial and/or numerical problems that can be addressed by GA. Particularly in the case of combination of these two kinds of problems, drastic expansion of searching space can be seen as a tough test for GA's searching ability. How to utilize Genetic Algorithms, how to convert design problems and how to effectively control the scale of searching space are three major subjects in optimizing architectural designs using GA. In this paper, the optimization of modeling for schematic design of ancient Yangzhou South City-Gate Ruins Museum exemplifies the introduction of the application process for optimizing architectural designs with the help of GA, as well as the disclosure of both advantages and disadvantages of GA by comparing it with other non-heuristic algorithms.

2. Background

In order to preserve the historical remains – the ancient Yangzhou South City-Gate Site – a large shell structure is designed as a museum to shelter the ruins. For the sake of avoiding any damage to the site, no strut is provided within the site area to support this large-span structure with the scale of 80 m long, 40 m wide and 11 m tall. As designed, the whole structure is composed of several irregular triangular faces while each face is filled with textures of regular angles formed by steel beams interconnected horizontally and vertically (Figure 1). It is clear that continuity and completeness of the textures are important factors affecting the performance of the whole structure. However, since the shell shape is irregular, it is difficult to ensure the textures' continuity at turning points of some triangular faces. Therefore, the primary task of optimization is to minimize such discontinuous edges.

In addition, in order to guarantee sufficient spaces for the convenience of construction treatment, the intersection points, i.e., vertexes of each regular triangle in the textures, should be kept away from the turning points as further as possible.

Since building structures and shapes are subject to changes of design purposes during the design process, optimization programming is also required to provide immediate and direct feedbacks on design changes.

3. Modeling

In order to simplify issues, an abstract geometrical model is introduced to describe the building structure as a whole, with beams and nodes turned into abstract line segments

Figure 1 Structure of the shell.

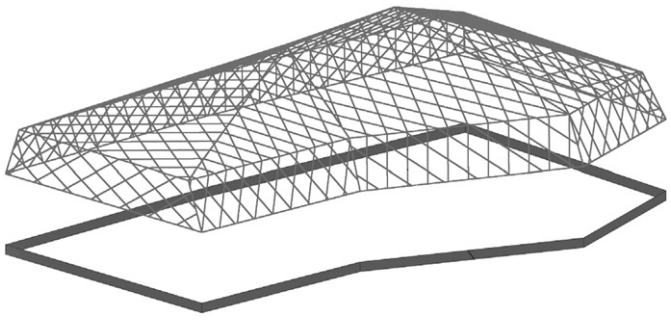

Figure 2 Abstract geometrical model.