INTELLIGENT PARAMETRIC BIM SOLUTION AND OPTIMIZER FOR DIAGRID HIGH-RISE STRUCTURES

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INTRODUCTION

With the aim of improving the functionality and resource-efficiency, many research projects in recent years have focused on various characteristics of high-rise structures–e.g., comparing the performance of different structural systems, components and materials, geometric optimization and integration with other systems [1-4]. A common section in their research design is the appliance of simulation-based case studies. Due to the large number of structural elements in tall buildings, one of the challenging and time-consuming stages of such studies is the initial geometric modeling phase prior to the structural analysis. The significance of the structural models is remarkable as they also act as the base for other models (architectural, mechanical, electrical, etc.) because they include all the main axes of beams, columns, core walls and boundaries of floors. Any inaccuracy, missing or superfluous objects in the models may cause errors during the process or incorrectness in outputs. For high-rise structures with relatively complex geometries, e.g., diagrids, especially with non-orthogonal overall forms, the procedure of preparing a single preliminary geometric model of the whole structure—when done manually—may approximately take hours to days.

This paper presents an intelligent multiparametric BIM solution which is able to generate multiple models of diagrid high-rise structures (with core, and cylindrical overall form or regular polygonal plan shape) in an accurate and quick manner. Moreover, it is capable of applying the geometric optimization method for diagrid structures–developed by K.S. Moon et al. [3]–to the models.

METHODOLOGY AND RESULTS

By employing the principles of Algorithmic Thinking [5,6] and by means of the programming and visual programming languages of Python and Grasshopper, an algorithm was designed and developed in the environment of the computer-aided design application of Rhinoceros (version 5.0). The reasons for this selection were: (1) the high-accuracy and advanced geometric functionality of Rhinoceros; (2) the inclusive parametric platform of Grasshopper which makes it possible to connect models to several other parametric engineering platforms at the same time or for further studies (3) simplicity, robustness and the open-source nature of Python and its growing libraries.

The algorithm has two main parts: One starts with multiple potentially independent variables as input parameters (e.g., number of segments of the base polygon, geometric density of the diagrid pattern, number of floors, floor-to-floor height, radius of the inner and outer tubes, spans of the main and secondary beams, etc.) and geometric model of different elements, collected in separated groups, as outputs (e.g., slabs, various beams, diagrid elements, core walls, etc.). Using the genetic algorithm of Galapagos [7], the second part is an optimizer which is an evolutionary solver loop connecting the aforementioned outputs and inputs. The numerical values of the optimal angles for the diagrid elements (the findings of the research by K.S. Moon et al.[3]) is merged as the fitness criteria in this phase. It is worth mentioning that the algorithm is intelligent enough to avoid logical errors and producing useless models (overlapped geometries, or empty set outputs which may cause errors in running other potentially interconnected BIM applications).

Figure 1 shows a few models generated as a test example. **The test example specifications: (1) Hardware and Operating System**: Processor: Intel® Core™ i7-4720HQ CPU @ 2.60GHz, Video Cards: Intel(R) HD Graphics 4600, NVIDIA GeForce GTX 960M, HDD: 1TB, RAM: 16GB, OS: Windows 8.1 64-bit; **(2) Building Spec. (given parameters):** number of floors: 40, floor-to-floor height 4.08m, core radius: 9.5m, envelope radius: 21m, etc.; **(3) Example Question:** What is the optimum number of segments of the polygon (plan shape)?; **(4) Answer:** 64, found in approx. 7 seconds, number of generated and tested models: 47.

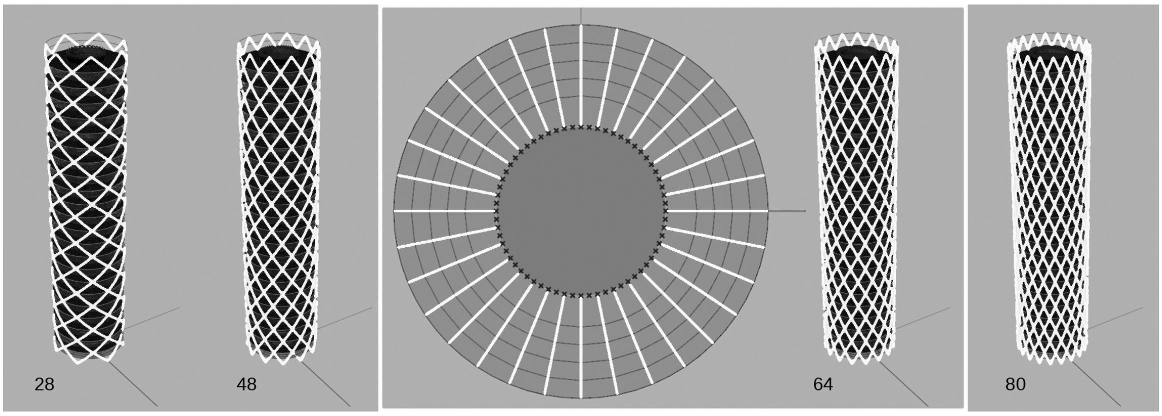

Figure 1. Four of the 47 generated models in approx. 7 seconds (from left to right polygons with 28, 48, 64, and 80 segments). A plan view example shows the modeled slab, core wall and beams elements–in the middle of the figure.

DISCUSSION AND CONCLUSION

The presented BIM solution significantly accelerates the process of accurate geometric model generation and structural optimization. Regarding the former, as the geometry of cylindrical diagrid systems is relatively more complex than those of most of other typical structural systems in tall buildings (e.g., orthogonal rigid frame, framed tube or truss-tube with rectangular plan shapes [8]), the outputs of this solution could also serve as blueprints to generate the other types. Alternatively, parts of the algorithm could be deactivated or modified for further customized setups.

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