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A new method for reusing building information models of past projects to optimize the default configuration for performance simulations

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ABSTRACT

The purpose of this study is to develop a new system that automatically generates default configurations for simulations during early phases of building design. The system is expected to facilitate front loading, which can contribute to making the building design process more efficient and consistent. The default configuration is generated based on an existing building database created by an architectural firm for each architectural program. The increase in the use of building information modeling (BIM) will allow for the compilation of a sufficient amount of data to utilize this system. The optimal default configuration changes its features automatically to match the objective functions employed by each architectural firm. Moreover, it can be used to create a generic building type, such as green buildings, based on a green building database. In this paper, a basic concept that can be used to produce a default configuration from existing building datasets was proposed. Using a case study, the similarity between the default configuration design and optimal design is illustrated. The study demonstrates the potential ability of this method to prevent designers from making careless mistakes with initial condition inputs and to eliminate the need to rework the simulation process, which facilitates front loading.

1. Introduction

The recent innovation known as building information modeling (BIM) [1,2] is a topic of discussion in almost every architectural firm. BIM adoption has the potential to facilitate front loading, collaborations during early phases of building design between architects and engineers, which can contribute to making the building design process more efficient and consistent. However, this tool has not yet been utilized efficiently. A key advantage of adopting BIM technology is its reusability [3,4]. Previous designs recorded in a database using BIM protocol can be used in future designs. This research considers the attributes of the classes in the object-oriented databases employed in BIM protocols, in which the building information is represented as the assembly of objects. The objects comprise any information, including the building elements and locations. This research investigates how such a database of previous designs can be used to generate initial designs for a new project to advance the design from the starting point for the implementation of the front loading.

The adoption of BIM will create a database of building designs. The utilization of the database will play an important role in increasing the efficiency and accuracy of building design. Data entered in early design stage can be applied in the later design stage of the same project to minimize the effort of data re-entry. Some architects/researchers are considering using the approach for planning operations and facility management strategies as part of the building life cycle. [5]. However, few studies focus on the reuse of information for another project.

Some studies have proposed the addition of data templates to subsequent projects using BIM [6]. The studies, however, do not refer to the correspondence between the previous and subsequent

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projects, as is considered in this study. Some studies have emphasized the importance of identifying the correspondence between the design variables and building performance. One study suggests that the knowledge gained by the simulation approach during building design can help design teams to discover important patterns that can be used to improve building designs [7]. Another study suggests that distinguishing the correspondence between inputs and outputs in simulations during building design can improve the efficiency of design optimizations [8]. This study is also based on the idea that the data analysis of simulation results can provide useful information that can be employed to improve building design. One of the unique points of this study is the extension of ideas across different construction projects to enable the application of the knowledge gained from previous building designs.

In this paper, the basic concept to produce the default configuration from existing building datasets is reviewed first [9]. Then, through a case study, the detailed process of the derivation of the default configuration and its potential to improve the design optimization process is presented. The default configuration of building design is a set of design variables that define the initial design of the building based on the past experience. The present study proposes an approach to best define the default configuration (i.e., an optimal default configuration) based on a large number of similar design projects, which are assumed to reflect the general design philosophy and approach of the design firm/architect. Proposed method make use of the experiences accumulated from the past projects, and documented as BIMs, and has the ability to synthesize and generate a default configuration that is superior to any of the existing design. As a result, it has the potential to improve the efficiency of the performance-based design process where a large number of design scenarios need to be evaluated.

2. Objective and scope

Building design is an optimization process [10,11]. An architect or engineer searches for an optimal building design that satisfies various objective functions based on the client's needs and the architect's or firm's philosophy. At the same time, designers must work with constraints based on site conditions and building codes. The final building design is subjected to an optimization process. Although it may be difficult to develop the best design solution due to limited design conditions, the superior design candidate should be selected and inferior design candidates should be eliminated in the design process. In this context, the final design candidate for each project condition is regarded as the optimal solution among the candidates in the design process. Based on this requirement, a database of existing building designs can provide an optimal design solution set that is based on lessons gained from construction projects under various conditions.

Each building design possesses distinct objective functions and constraints. The degree of importance for each objective function is dependent on the design philosophies of the architects and clients. Therefore, it is impossible to develop a single optimal solution based on a single objective function. It is also impossible to consider these differences as superior or inferior to each other when comparing different building designs. All designs must represent optimal solutions for each building condition. In this context, the optimal solution set is referred to as the Pareto-optimal solution set when it is impossible to determine the superiority of each solution.

The optimal solution set is based on a certain objective function that influences the features of the building. If two firms have different design philosophies, their design datasets will have different features in their Pareto-optimal solution sets. Thus, a firm's Pareto-optimal solution set must be unique because it has been influenced by the firm's individual philosophy.

Most architectural firms use a design review system. Generally, a veteran architect or engineer who has significant building design experience checks the design at the end of each design phase and provides feedback. The veterans use their intuition to find discontinuity in the designs by comparing the design to their previous experience. The discrepancies between the design and their experience lead to a closer investigation of the design details. This process is identical to that used to check whether a proposed design for a new project fits into a Pareto-optimal solution set accumulated by the veteran.

With this idea in mind, building design is defined as a process of creating conditions for a new building project under objective functions and constraints to fit into the existing Pareto-optimal solution set. To this end, a default configuration is required to provide the initial data for a new project. The distance from the default configuration to the optimal solution informs the designer of the project's estimated time, cost and difficulty. Including the default configuration in the Pareto-optimal solution from the start of the design process is an ideal solution for creating effective designs.

The most efficient way to create a default configuration is to reuse existing building design data. Some studies have proposed the inclusion of a template used in existing building designs [6]. This function has been employed in some simulation tools [12] as the user interface for EnergyPlus [13]. However, it is difficult to ensure the adequacy of the template because it is created by each architect or engineer using the program. Thus, the usefulness of the template depends on the experience of each architect or engineer. Although the template may be created by a veteran architect, the virtually infinite variations in building design would make it difficult to create a template that is sufficiently robust to be applied to any type of project. Such an exercise is beyond the architect's or engineer's capacity and requires a computational system. One possibility for this system is the generation of an automatic default configuration that utilizes an existing building design database. This system will work efficiently if it can retrieve and reuse relevant data to create a default configuration for a new project.

The features of an automatically generated default configuration will depend on the dataset being utilized. If the composition and features of the dataset change, the default configuration will change as well. Thus, the default configurations will change with the design trends. Building projects are not static, and the optimal solution for a particular building design is always improving. In this context, a default configuration based on the existing building database would require daily improvement. Building a database of improvements will help to revolutionize optimal building design.

As a design project progresses, designers gain more understanding of its potential for success. Selecting appropriate reference data in the existing building dataset benefits the system, and this referenced data being used for the default configuration should evolve as the design phase progresses. By extension, the default configuration for unfixed design parameters must also be improved as the project progresses.

In this paper, a system to generate the default configuration automatically is proposed. To illustrate the system, a building design dataset is required. First, a building design dataset for the trial is created. Then, the method used to generate the default configuration based on the dataset is described. As mentioned above, the default value must be improved through iteration, and this improvement is performed through the addition of new building design data to the existing dataset and through the alteration of reference data for each design phase. Then the transience of the default configuration through the inclusion of these factors is illustrated. Finally, the accuracy of our method by comparing its results to the optimal solution results to examine the gap between the default configuration and optimal solution is discussed.