Developing a Performance-Based Design System with Semantic Interoperability

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Abstract. This paper presents an attempt to develop a performance-based design expert system intended to automate the checking of building code compliance. The proposed system may be used repeatedly throughout the design phase, from the earliest stages of development to the end of the design process, in order to improve the efficiency and quality of the design and to decrease the occurrences of design misapplication. Two of the critical issues in the development of the rule-based expert system presented here were the data modeling of building codes to be used as a knowledge base, and the algorithm for the application of this knowledge base. Both an object-oriented and a constraint-based approach to these issues are discussed in this paper. This paper gives a detailed overview of "CODE-MAVEN" as well as discussing an intelligence-based intuitive and graphical interface for the system that will also contribute to increased feedback on designs.

Keywords: building code, rule-based expert system, data modeling, object-oriented design system.

1 Introduction

This paper discusses an attempt to develop a rule-based expert system for real-time checking of building code compliance. They are legal regulations that have a direct influence on buildings from the very beginnings of an architectural proposal and throughout the phases of architectural planning, design, and construction. In particular, building code compliance must be thoroughly checked in the planning and design phase, if one intends to improve the efficiency and quality of the design and to decrease the occurrence of misapplications (Park, 1993). One may also assume that stringent checks on building code compliance will increase design feedback by offering a variety of alternatives methods. Not surprisingly, research into and development of expert-based systems for the analysis of building code and its compliance has been underway in a variety of places across the globe.

This paper details the development process of the rule-based expert system called CODE-MAVEN. Its particular focus is on establishing knowledge bases, data models, and algorithms for rule-based systems. At the end of this paper, we present

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our successful development of a rule-based expert system for building code compliance checking. The conclusion also includes an outline of the research and development issues to be considered next.

2 System Overview

Despite this recent development and interest, however, systems for building code analysis have not been entirely successful and so the occurrence of real-world industrial applications of rule-based expert systems is still rare (Sinz, 2002). The reason for this scarcity is that these expert systems have generally been developed separately from already existing design tools. Accordingly since these newer systems do not have a sufficient understanding of geometrical shapes as well as semantic meanings, building code checks on various complicated models that also include site details are not completely implemented. To fundamentally resolve this problem, we began by investigating the building data model of an apartment and then developed a data model based on ArchiCAD^{TM} which was designed to be flexible, extensible, and easily applicable. Also important was the classification of building codes for storage in a rational database: building codes were classified by their application procedure and then stored computationally in a relational database that we call a knowledge base, based on the data model for a database. Finally, this knowledge base was connected with a constraint-based system for checking building code compliance that is currently under development, which should, when completed, fulfill the need for an effective analysis tool for compliance checking.

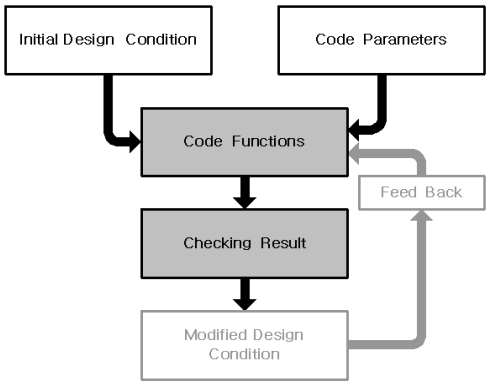

Fig. 1. The architecture of CODE-MAVEN

This system is composed of three parts: the design conditions, the code parameter called the knowledge base, and a rule-based system that includes code functions and results checking. we adopted a rule-based system from the infant phase of Artificial Intelligence as being practically applicable for the analysis of building codes. Figure 1 illustrates the architecture of CODE-MAVEN. The design conditions consist of modeling by ArchiCADTM and the specific conditions for code checking. Checking results will continuously modify the design condition at any level or any time during the design process.

The knowledge of building codes is composed of a set of provisions and relations governing the design of buildings (Yang, 2004). Generally, in Korea, the checklist of building codes for an apartment is classified by the land-use plan, the examination of area, the examination of height, the examination of interval, and so on. This

classification is closely related with site planning. The building code provisions and regulations for the apartment are extracted according to the classifications on the checklist.

3 Implementation

To implement our system, we initially entered information about the design conditions. The design conditions for building code compliance checking are divided into two parts: project conditions and specific conditions. Project conditions such as the province, the area, and the circumferential environment are added by defining each condition, while specific conditions such as unit floor plans, parking areas, and outdoor spaces are added by using and customizing the parts library, as well as making new drawings. The functions in the modeling group are used to establish design conditions; those in the code-checking group are used to evaluate building codes. These functions were developed using ArchiCADTM, API, and C++.

After completing an apartment design, the users can perform a building code compliance check on their design. CODE-MAVEN returns results graphically in two- and three-dimensional interfaces to visually represent non-conformity with the building code, as well as providing numerical information. The interface also provides the manifold color necessary for intuitively distinguishing differences, particularly in areas where code checking is related to views and natural light levels. These diverse results are illustrated in Figure 2.

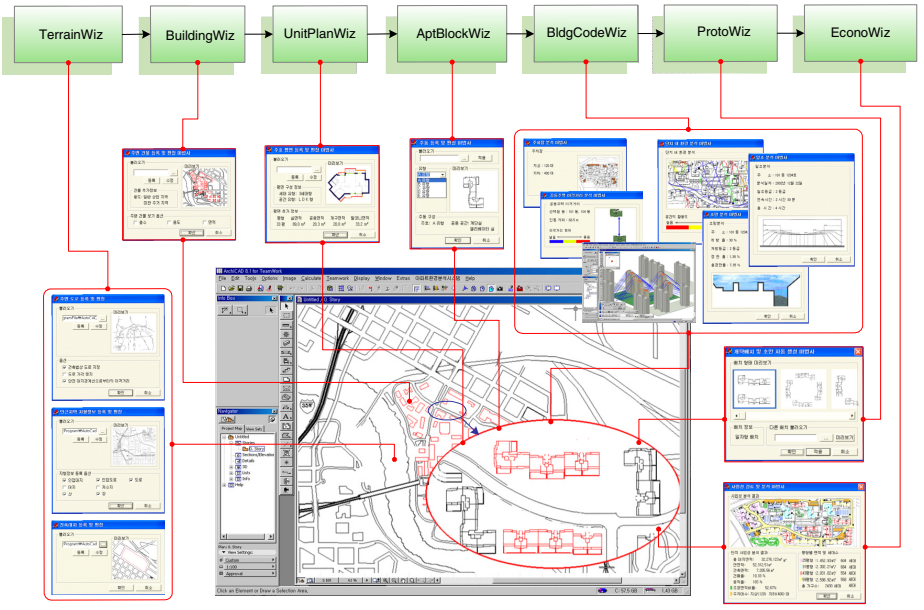

Fig. 2. The feature of graphical check and numeric information

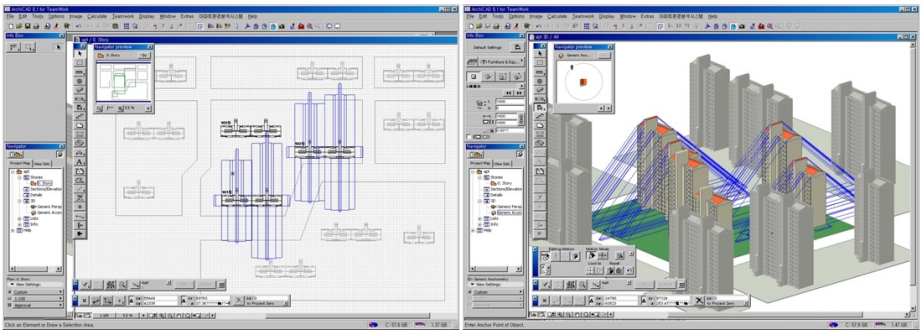

Fig. 3. The execution example of CODE-MAVEN for checking the distance among the buildings

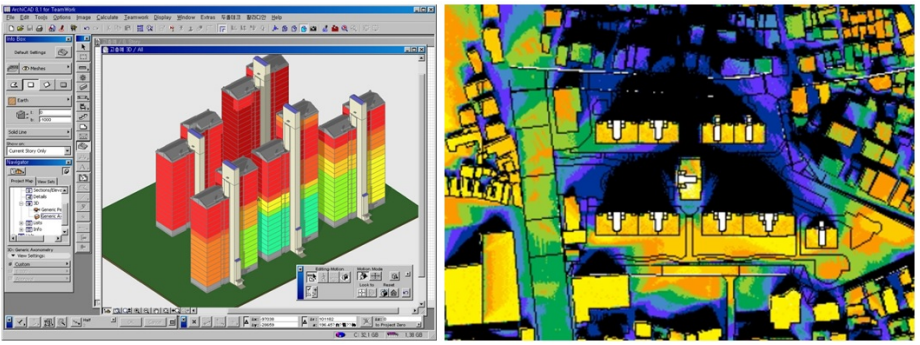

Fig. 4. The execution example of CODE-MAVEN for checking the time of sunlight and shadow

Figure 3 shows the execution example of CODE-MAVEN for checking the distance among buildings and between buildings and road. CODE-MAVEN can calculate automatically the height of building and draw blue lines which show the region of building shadow because each objects of CODE-MAVEN have the parameters of the geometry of building, site, and road. Therefore, the users easily figure out the condition o0066 buildings placement and check the building codes. And also, CODE-MAVEN can alert the violation of building codes.

Figure 4 show the execution examples of CODE-MAVEN for the analysis of sunlight. CODE-MAVEN calculates the period of sunlight with the position of sun which ArchiCAD provides by each time of a day and shows the color index according to the time of sunlight. The figure of left down of Figure 4 illustrates the area of shadowing in a day.

4 Conclusion

In this paper, we presented a rule-based expert system, CODE-MAVEN, which integrates building code compliance checking within the design process in a real-time fashion, and is based on ArchiCADTM, and gave a practical example of the

development of the system. In general, many expert systems developed to analyze building codes are separate from the existing CAD engine, in turn limiting the development of systems designed for code compliance checking. This system, however, has been developed specifically with the practical and commercial use of compliance checking in mind. We expect that CODE-MAVEN will be effectively utilized throughout the entire design process, from its earliest stages to its final ones. Architectural designers will be able to generate and then immediately check various design options and alternatives in the schematic phase, which will, we believe, result in a decrease in design misapplication and an increase in design efficiency.

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