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Real-time management of spatial information of design: A space-based floor plan representation of buildings

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Abstract

The current trend towards globalization forces the AEC community to change its practical approach from a non-systematic, labor-intensive to a systematic one. Based on the paradigm shifted from 'drawing' to 'constructing' in architectural design practice, this paper focuses on developing a new type of CAD system that automatically constructs and manages well-structured floor plans with minimum geometrical input from the designer. The paper also took advantage of the building data models developed from the prior research. The model includes hierarchical building components such as 'building', 'plan', 'space', 'ring', 'wall skeleton', 'surface', 'column', etc. The creation algorithm developed assures a semantically rich and structurally correct floor plan at any point in the design process. In particular, the floor plan constructed through the design process contains spatial information as well as other design information about the building components. Thus, the system effectively manages spatial design information in the real-time basis. Since the system implemented on the basis of the algorithm is the very first step toward a complete intelligent CAD system, research and development issues to be considered next are identified at the end of the paper.

Keywords: Spatial information; Floor plan representation; Building data model; Component-based CAD

1. Introduction

The current trend towards globalization forces the AEC community to change its practical approach from a non-systematic, labor-intensive to a systematic one. The need for the paradigm shifted from 'drawing' to systematically 'constructing' for design practices is also recognized. However, the dominant usage in the building industry is still based on using CAD as a graphics editor. [3] Consequently, most CAD systems only support drawing works. They only manage graphical information, and are weak to consistently manage design information being generated during the design process. Due to this weakness, drawings are often not consistent and one change in a drawing consequently causes too many changes in other drawings.

To solve these problems, current trends in the CAD software industry show a main stream approach based on an object-oriented paradigm that integrates 2D and 3D data and representations. Some commercial software packages, such as ArchiCAD, All Plan, AutoCAD ADT, are based on the object-based paradigm integrating 2D and 3D design information. Research efforts [1,4,8,11,12] in the academia have also showed great interest in the issues that include how to systematically manage spatial information and how to manage and deliver design information by standardized formats such as the IFC (Industry Foundation Classes) model.

The goal of this study is to develop a computational mechanism which defines design objects as building components such as walls, slabs, columns and openings based on the object-oriented paradigm, and constructs a building consistently and systematically with the design objects. Special emphasis is placed on developing a computational method to manage spatial design information instantly and consistently that has been long time ignored in the conventional CAD systems. Here, a space means a room enclosed with walls, such as a living room

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or a dining room, or outdoor space defined by outside wall envelope.

The researchers observed two things: one is that conventional architectural design focused on the floor plan design; and the other is the notion of architect as composer. Louis Kahn, a great modern architect, mentioned in a lecture in 1966 that an architect should be a composer who composes with building elements as design entities. Based on the observations, this study employs a design method to construct a floor plan with design objects that automatically define a complete three-dimensional building.

This study is the first step toward a complete intelligent CAD system and focuses on how to generate a simple well structured floor plan. Therefore, the scope of the research is limited to the construction of a single-story building. More advanced features such as editing a floor plan fluently and evaluating it with various design criteria could be the next research topics.

2. Related works

There has been some research on developing CAD systems that can build structured floor plans [2,4,11,12]. In such systems, a floor plan is structurally well defined by having some hierarchical components. Since space and form are the two main aspects to define a building, they should be represented at the same time within a system. To be more effective it could take an object-oriented approach where each building component is an object from the view of the object-oriented paradigm. That is, the object has its own data and methods of how to behave in certain situations.

A space-based representation is also examined in Mahdavi's recent research (1999). Trying to integrate detailed simulation methods and CAD systems, he recognized the importance of spatial information. He observed that detailed thermal simulation methods require the definition of spaces and zones, and not just bounding surfaces. Almost all currently available commercial CAD systems rely on building representations that do not include spaces.

Carrara's research (1994) focuses on using spatial information on the very first stage of the design process. The concepts of Space Units (SU) and Building Units (BU) that the researchers employed allowed the system to represent the defined SUs as bubbles, highlighting the adjacencies and the defined paths. An interactive graphic approach [7] was attempted to solve spatial allocation problems in facility layout. The study introduced the concepts of 'stack plan', 'zone plan', 'block plan', and 'one to one plan'. To generate a best block plan a designer employed a process of generation, adding/modifying criteria, and appropriate trade-offs in an iterative, interactive fashion.

3. The concept of the 'structured floor plan'

The core of the study demonstrates how to construct a well-defined, well-structured floor plan (Fig. 1). In this paper we refer '*structured floor plan*' [2] to a floor plan composed by the designer in which its components are well structured and thus effectively express its architecturally meaningful structure. Such a plan has the following characteristics.

1) Object-oriented: The designer constructs a floor plan with predefined design objects such as walls, columns, slabs, and openings.
2) Definition of relationships between building components: It defines relationships between building components as design objects as well as their geometrical locations.
3) Management of spatial information: Spatial information as well as formal information is important in architectural design. Thus, it automatically manages spaces enclosed with wall components.

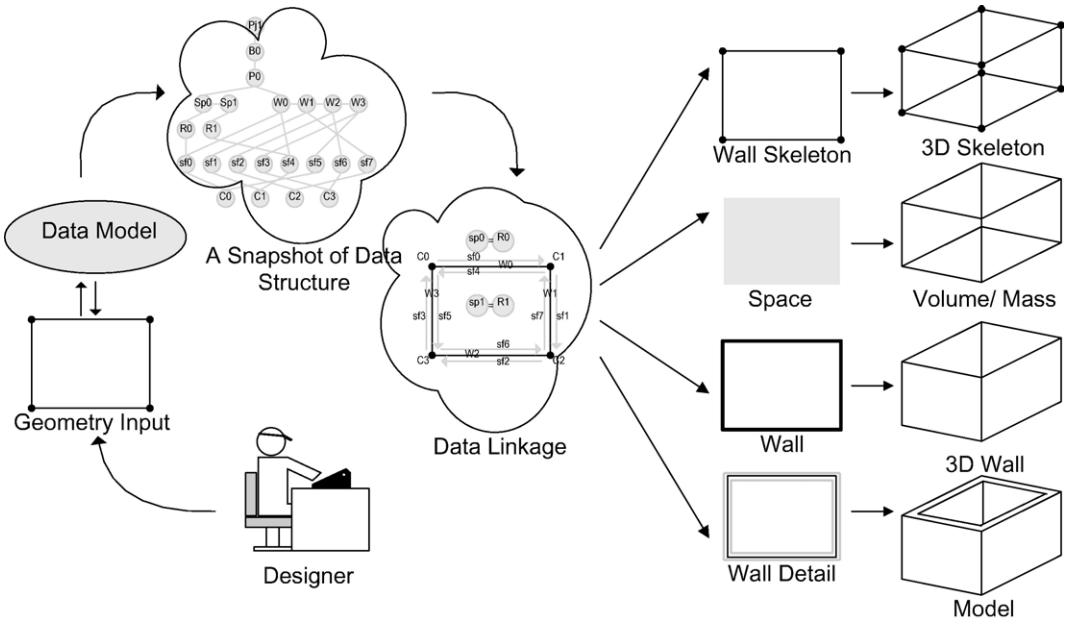

Fig. 1. The concept and principles of the 'structured floor plan'.