The Application of Artificial Intelligence Paradigms to Architectural Layout Generation

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Introduction

The development of systems to produce architectural layouts from a set of spaces has been an objective of design researchers for over two decades. These research efforts have spanned a diversity of computational approaches from the use of mathematical optimization techniques to the present emphasis on knowledge-based reasoning paradigms. The evolution to these knowledge-based paradigms has brought about the initiation of numerous issues into all aspects of the layout generation research domain. Considerations related to one segment of this domain, the layout generation process, are currently being addressed in the Computer-Aided Architectural Design Expert (CAADIE) project at the Center for Integrated Facilities Engineering (CIFE).

This paper presents an introduction to the CAADIE project including an overview of the research objectives associated with the application of knowledge-based paradigms to the layout generation process. In addition, the preliminary results achieved in the research will be highlighted together with a summary of the future goals for the project.

CAADIE Overview

The CAADIE project endeavors to explore the potential for utilizing knowledge-based paradigms in the development of conceptual layouts. In particular, the project emphasizes the generation of conceptual design diagrams. The system is being developed as a computer-aided design tool, to work in cooperation with a designer, to produce the conceptual diagrams such as bubble and block diagrams. It is intended that the system will complement the expertise of the designer by using experiential knowledge provided by the designer, in conjunction with the CAADIE knowledge base, to provide useful assistance.

The primary CAADIE goal of developing a knowledge-based design support tool incorporates several objectives including the development of a design knowledge model, the identification of layout heuristics used by designers, and the implementation of a control structure which facilitates the generation of knowledge-based layouts. In addition, the project addresses secondary topics such as graphical representations and user interface requirements. Based on these objectives, a prototype of the CAADIE system is currently under development. The results of this development effort constitute the basis for the discussion of the issues presented in this paper.

The Knowledge Model

The initial emphasis of the CAADIE project has been the development of a model which provides a framework for the layout generation knowledge. Based on this work, one potential framework has been developed. This model represents a characterization of the design process knowledge and the layout information used by a designer.

The characterization of layout generation knowledge consists of the categories of knowledge employed during layout conceptualization. These categories include design attribute heuristics,

spatial ordering heuristics, knowledge selection heuristics, and designer expertise. These categories represent the experience and intuition of the designer. The characterization of layout information features the categories of information required to identify typical layout constraints. This includes topological attribute (dimensions of spaces), design attributes, and spatial ordering concepts. This information is used to support the decision making process involved in developing a conceptual layout. These two characterizations form the model's premise that the consolidation of both layout generation knowledge and layout information are essential to the successful generation of a knowledge-based layout.

In addition to providing a theoretical characterization of the layout knowledge, the definition of this model has provided a structure for developing the system prototype. The knowledge categories described above are currently being implemented as frame hierarchies and rule sets in the prototype. Finally, this knowledge model permits the researchers to compare and evaluate other design systems that generate conceptual layouts. This classification by knowledge categories is necessary in a research environment where new systems consistently appear with varied claims and premises.

Layout Generation

In addition to the development of the knowledge model, the CAADIE project encompasses a prototype capable of generating conceptual stage bubble diagrams. Within this generation process, the application of knowledge-based paradigms notably impacts two prominent issues; the order of spatial placement in a configuration and the process of generating placement options. The following sections highlight this generation process in the system, and the significance of applying knowledge-based paradigms to this process.

Space Selection

The issue of space selection focuses on the reasoning required to determine the order of spatial placement within the layout generation process. In traditional algorithmic-based systems, static selection processes exemplified the majority of solutions to this matter. These processes predominantly focused on the selection of spaces based on total area requirements or the number of adjacencies required by each space. This emphasis on static selection procedures is supplanted in the prototype by a rule-based selection procedure. This rule-based procedure captures the reasoning used by a designer during the space selection process. This reasoning transforms the ordering to a flexible process which conforms to the given design circumstance. For example, a selection rule exists in CAADIE which recommends the selection of a space which is a required adjacency of a previously placed space and which has similar design requirements to the space. Although this selection rule represents only a slightly more complex set of selection criteria than the static selection methods, a compilation of these rules provides a system with a level of expertise notably greater than that of algorithmic selection routines.

Configuration Generation

The generation of conceptual diagrams within the prototype emphasizes the use of knowledge-based paradigms to address the constraints and requirements of each space within the layout. In contrast to traditional layout generation systems which incorporated mathematical algorithms for determining the potential placement of a space, the CAADIE prototype incorporates a combination of rule-based reasoning and frame-based representation to determine the appropriate spatial placement options. The rule base provides the system with a representation of the reasoning a designer utilizes in the layout conceptualization process. In conjunction with this rule base, the previously discussed knowledge information categories contain requirements in a frame-based representation for each space. Therefore, the system is capable of combining the reasoning of a designer to determine the general placement of a space, with the requirements stored in the spaces to refine the placement options. For example, a general placement rule within the knowledge base recommends that a space should be

placed adjacent to another space if the two spaces have a required adjacency. When combined with specific design requirements such as sunlight and security, this general placement option is refined to an actual placement location.

Conclusion

In summary, the CAADIE research project represents an effort to apply knowledge-based paradigms to the layout generation process. In particular, the issues associated with the definition, representation, and utilization of design information and knowledge embody the primary efforts in the prototype development. The continued research into these objectives forms the basis for the future development of the system and the overall research effort.