A LAYOUT GENERATION SYSTEM FOR ELEMENTARY SCHOOLS

SHEN-GUAN SHIH, TSUNG-PAO HU,
Department of Architecture,
National Taiwan University of Science and Technology,
Taipei, Taiwan

Abstract. This paper describes a layout generation system that is realized by adapting the design problem formation and design process of the well-known SAR method. The purpose is to examine the idea that some certain types of design problems can be greatly simplified by conventional design techniques such as hierarchical decomposition, zoning, module, and most importantly, the concept of “support”, which is a spatial framework that dissects the planning site into sectors and zones of various spatial characteristics.

1. Introduction

Layout planning has been an intensively studied issue in the research community of computer aided architectural design. Many powerful search engines have been devised to identify good or optimal solutions for layout planning problems. It has been shown that even a moderate size problem may contain a huge number of possible alternatives. However, layout generation systems have not been very desirable to common designers in the commercial market. We have addressed two possible reasons:

1. Architectural layouts are usually quite flexible and lack of definite objectives. Architects do not need precise and optimal solutions in the process of layout planning. The input and output of automatic layout generation systems must be integrated into an appropriate level of abstraction in conventional design processes.

2. The manipulation of layout generation systems may require information and skill that are not commonly attainable to architects. Design constraints and objectives that can be formally defined with mathematical terms, which are often required for automatic layout generation systems, are remote to common designers.

SAR is a systematic layout generation method developed by Habraken in the sixties, when computers were not common tools for architects. The method uses
conventional design techniques such as hierarchical decomposition, zoning, modules, and most importantly, the concept of “support”, which is a spatial framework that dissects the design site into sectors and zones of various spatial characteristics such as accessibility to fresh air, natural light and specific activities. Such grid systems are often used as one of fundamental techniques to organize and to analyze architectural forms (Tzonis 1986). It is realized that these conventional techniques, which are familiar to most architects, are effective guidance to discover solutions in problems of layout planning. Using layout generation of elementary schools as an example, the purpose of this paper is to describe and to evaluate the way of applying such techniques to the development of computer assisted design environments.

2. The layout generation system

The layout generation system was devised by making some generalization to SAR method (Boekholt 1974). Due to some changes we have made to the original definition and context, we shall use the terms “spatial framework” and “design unit” instead of “support” and “infill” in SAR system.

2.1. THE SPATIAL FRAMEWORK

The spatial framework divides the planning site into partitions that can be characterized by a set of attributes concerning some environmental factors or geographic features such as traffic, noise, slopes etc. The spatial framework, with attributes of environmental factors assigned to every partition, defines a basis for the evaluation of the placement of design units. For example, the diagram in figure 1 shows that a planning site is associated with a spatial framework to analyze environmental noise intensity.

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  1 1 1 3
0 0 1 2
0 0 1 2
0 0 1 2
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*Figure 1 Analysis on noise intensity of the planning site*
Other environmental factors such as accessibility to traffic or some specific resources can be used to analyze the site as well. Potentially, the form of the spatial framework can be a tartan grid, a hexagonal grid, a polar grid or other shapes that is chosen by the designer to organize the spatial characteristics and his/her design conception.

2.2. DESIGN UNITS

Design units are functional spaces that are to be placed on the site. Grouping related spaces in different levels of abstractions can derive a hierarchy of design units. Figure 2 shows one spatial hierarchy we have applied to layout planning of elementary schools. The root of all design units in one level is associated with a spatial framework to initiate the layout planning process. Once all design units in the same level are placed, the planning process can proceed by tracing down the hierarchy until reaching the end.

2.3. LAYOUT GENERATION

In the process of layout generation, each design unit may occupy one, or more than one partition in the spatial framework. The dimensions of design units and the spatial framework should conform to a module that is derived by analyzing the requirements and the site. The enumeration of all possible layouts can be derived by a depth first search. The process can also be formulated as a semi-assignment problem (Kennington 1992). Using a set of network nodes to represent desirable units and a set of nodes to represent available locations on the spatial framework, the arcs that link the two sets of nodes may represent the evaluation to the assignment of the design unit to that particular location. Finding all feasible solutions is equivalent to finding all possible assignments.

Figure 2. A spatial hierarchy for elementary schools.
with gross cost smaller than a given value. Figure 3 shows a network that formulates the layout planning as a semi-assignment problem. It is very likely that there are many more computational models that are capable of solving this problem efficiently.

![Figure 3. A semi-assignment model for layout generation.](image)

2.4. A TEST CASE

A program is written with AutoLisp to execute the layout planning process. We use a real case as an example to test the program. The site is 180 meters wide and 150 meters deep, with three sides surrounded by streets. A five by three grid, with 33 meters for each sector, is used as the spatial framework in the first level of planning. Environmental noise, accessibility to traffic and connectivities of design units are factors for evaluation. Figure 4 shows a part of the search tree, with eight terminal nodes representing feasible solutions.
The process can be carried on to the next level of hierarchy. The academic house is selected for further design in our example. In figure 5, the configurations and the dimensions of required spaces are studied to decide the module and the spatial framework of this level. Figure 6 shows two generated layouts for classrooms and other supporting spaces. Figure 7 shows three complete solutions for the academic house.
Figure 5. Studies of design units in the academic house.

Figure 6. Generation of classrooms and supporting spaces.

Figure 7. Three possible layouts of the academic house.
3. Conclusion

Architects work on abstractions. Automatic layout generation systems often require geometrical or topological constraints such as maximal and minimal sizes, spatial adjacencies; and quantitative objectives such as shortest distance or smallest gross area (Flemming 1992). However, in most cases, these constraints and objectives can be loose, or flexible to architects. Precise and optimal solutions regarding these constraints and objectives may not be as attractive to architects as to program developers. Space planning problems are very complex in terms of computation, but human designers can get around them manually with conventional techniques such as hierarchical decomposition, zoning, and modules. The central concept of the system is the spatial framework, which reflects the designer’s interpretation to the “spatial structure” of the site and the environment. Such grid systems are often used as one of fundamental techniques to organize and to analyze architectural forms.

The layout generation program that is described above does not generate very impressive result nor does it exhaustively inspect all possible alternatives. However, by using simplified problem formation and conventional design techniques to drive the generation process, it does offer a fair opportunity to get integration with conventional design processes.

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References