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3—8 A System for Extracting Aesthetic Information from Architectural Drawings

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Abstract

This paper presents research work in the area of analysis, extraction, and recognition of aesthetic information from architectural drawings. A computer-based system is developed that extracts the geometric and topological structure of a plan, detects wall-joints, and identifies axes of symmetry, hierarchies, proportions, and modularity within a plan.

1 Introduction

Along with the popularization of Computer-Aided Design (CAD), it has been becoming increasingly necessary and desirable for a computer to recognize drawings and diagrams. The recognition process can be used not only as means to input information into computer but also to extract and compare morphological attributes. Methods exist for inputting and recognizing engineering drawings and diagrams. This is primarily because they are drawn to conform to specific standards. In contrast, architectural drawings are not always prepared in accordance to existing standards. The problem of reading, recognizing, and extracting morphological information from them automatically remains unsolved. It is this problem that this work focuses on.

Research in the area of architectural document analysis is quite recent and, therefore, the pertinent literature is quite limited. One of the purposes of this work is to bridge the gap between computer vision and architectural analysis by addressing theoretical issues of morphological analysis through advanced computer vision techniques. Only a few systems for the recognition and interpretation of mechanical and electrical engineering drawings have been developed [1][2]. These systems incorporate knowledge about the type of drawing to be processed. In architecture, most computer systems are oriented mainly towards design and form making. One attempt to extract information from architectural plans that go beyond simple line and text identification has been reported by Koutamanis and Mitossi [3]. They described a technique for extracting geometric, building, and spatial elements in architectural designs. The system extracts skeleton lines from architectural drawings and produces a primitive model of a "bubble diagram." Another system for extracting elements from architectural designs has been proposed by Yessios and his collaborators. [4] Although intended to work as an expert system for library design, it addresses issues of form-extraction. The form-extraction part of the system was never implemented on the computer, but there are descriptions of techniques for extracting an architectural CAD model.

In this work, it is suspected that vision systems can enhance the conduct of morphological analysis by allowing the researcher to access information more systematically and efficiently. For example, the automatic extraction of formal rules from architectural drawings may provide one with insight concerning the designer's form-making approach and intentions. Computer systems are good at dealing with vast amounts of information, sorting, classifying, and analyzing it. In contrast, human experts are good at detecting higher level abstractions. Hence, it is more likely than not that morphological analysis can be enhanced substantially by the interaction of humans and machines. Thus, knowledge concerning the morphological structure of notable buildings and classes of buildings can be acquired.

Computer vision systems are designed to capture, analyze, and recognize visual information, create high level descriptions from sensed data, and, then, feed this information to CAD systems for further processing. In architecture, numerous benefits can be derived if systems for recognizing and interpreting architectural drawings are developed. These benefits can be assigned to the following categories:

1. Efficient means for inputting architectural drawings to CAD systems.

2. Management of the information contained in architectural drawings.
3. Extraction of information which, if performed manually, is time consuming and inefficient.

In turn, extracting, analyzing, and interpreting morphological information contained in architectural drawings is likely to lead to a better understanding of the formal attributes and relations exhibited by buildings.

This work addresses the potential of computer vision and pattern recognition techniques in architectural form making. A computer-based framework which extracts automatically the geometric and spatial structure of buildings is formulated, implemented, and tested. In addition, the framework can be used to extract various other morphological attributes (e.g., rhythm, proportion, and symmetry). Finally, it is possible to use this information to compare plans.

2. Hypothesis

Predicated on the assumption that designers derive knowledge from past solutions to form-making problems, this work examines the methods by which the morphological information which is contained in building plans may be extracted automatically and entered in a knowledge base. Conceptually, this is part of a larger project, which entails investigating how knowledge can be incorporated in a CAD system in a manner which informs and supports the form-making process. Conceivably, the approach taken in this work is, wholly or partially, applicable to the problem of extracting useful information from graphic representations used in a variety of disciplines (e.g., engineering).

Earlier, it has been argued that computer vision techniques may contribute to the investigation and analysis of the morphology of buildings. For example, such techniques may lead to a better understanding of the concept of visual style. Specifically, when each of several buildings create a similar visual impression, they are said to exemplify a particular *architectural style*. Given a finite set of buildings that are perceived to be visually alike in some way, systematic exploration and establishment of the basis of this likeness will constitute a foundation for investigating the concept of style systematically. This work provides a context within which the morphological similarities and differences between plans or portions thereof can be established and explored methodically.

Given the foregoing discussion, the hypotheses to be tested in this work are:

1. The geometric and architectural structure of plans and other two-dimensional line-based compositions may be extracted automatically.
2. Computer vision techniques may be used to investigate, analyze, and compare the morphological structure of building plans and other two-dimensional linear compositions.

3. Computer-Aided Extraction

The work presented in this paper focuses in three directions. The first direction is the design, implementation, and testing of a computer-based system, which allows a user to extract automatically the geometric, topological, and spatial information of a two-dimensional plan. The second direction focuses on the extraction of morphological information from plans, such as lines of global and local symmetry, hierarchical structure, proportions, and modularity. The third direction entails implementing a computer-based system, which is employed to compare morphological information of classes of plans. Computer vision and pattern recognition techniques are used to investigate, analyze, and compare plans of buildings from a morphological standpoint. Such techniques can contribute toward detecting differences or similarities between individual plans.

Computer-aided extraction techniques belong to a family of techniques referred to as computer vision systems. In general, computer vision systems attempt to recover useful information about the three-dimensional world from image arrays of sensed values. Vision algorithms try to detect relations among image data. These data are numbers representing light intensity or depth range.

A typical vision system operates in the following manner:

- Clears the raw image data from noise and outliers, that is, from extreme or missing information.
- Detects features, such as, edges and lines. This is done by observing local changes of the image's intensity. The detection of the geometrical information is similar to that of solving a statistical regression problem.
- Models the data in parametric form. This is usually referred to as segmentation and reconstruction. Here, the main task is to fit models to the image data. The process may employ regression techniques to fit a model or may deform the model to fit the data.
- "Recognizes" objects. This task is usually accomplished by comparing the sensed data to a given model. If a match occurs the object is

assumed to be "recognized," otherwise it is labeled "unknown."

4. Implementation and Results

AELI (Automated Extraction of Line-based Images) is a computer system for the processing, editing, and managing of two-dimensional line-based images. The AELI software is written in the Java programming language. The Java methods perform all of the graphic interfaces, which have been developed to take advantage of the multi-platform workstations capabilities (primary speed and color). The Java programming language has been used to implement all the algorithms related to image processing.

In the following paragraphs three sample plans are used to illustrate the process of extraction. The one on the left is Villa Malcontenta by Palladio, the one in the middle is Ueda residence by architect Tadao Ando, and the one on the right is a vernacular building. The first represents an orthogonal plan, the second a linear plan, and the third a non-orthogonal plan. Figure 4.1 shows the scanned images, Figure 4.3 shows the extraction process, Figure 4.4 show the geometric structure of the buildings, and Figures 4.7-10 show the extracted lines of symmetry, hierarchy, proportions, and modularity.

5. Significance and Future Research

The main purposes of this study are to capture, analyze, and recognize visual information, create high level descriptions from the sensed data, and, then, feed this information to CAD systems for further processing. In architecture, numerous benefits can be derived if a system for recognizing and interpreting architectural drawings is developed. These benefits can be classified into the following categories:

- Efficient input of architectural drawings into CAD systems.
- Management of the information contained in architectural drawings.
- Extraction of information which is time consuming and inefficient when performed by humans.
- Education tools for classifying and organizing images of buildings.
- Theoretical contribution to a better understanding of visual organizations.

In turn, extracting, analyzing, and interpreting the morphological information contained in architectural drawings is likely to lead to a better understanding of the morphology of buildings.

The scope of this project is not only to recognize morphological information in architectural drawings but to provide a framework that will allow a computer to analyze and classify systematically and efficiently such information. The project may eventually lead to a computer system that will: (a) provide to the user/designer useful information about drawings, (b) test whether it is possible to have a computer "recognize" compositional principles, and (c) allow the user/designer to manage large databases of images and organize, query, and index them on the basis of morphological attributes. If humans are able to make judgments based on morphological principles, it may be possible to develop tools that will eventually allow similar judgments to be made by computers. Of course, it is not expected that, at the beginning, such judgments will reach the level of complexity of judgments made by humans. Yet, it is expected that, since computers are more powerful than humans in certain areas of processing, such as computation, precision, and speed, they probably will contribute significantly towards making the work of humans more systematic, efficient, and, therefore, more effective.

The present study was confined to extracting knowledge only from plans of buildings. As a future direction, it will be necessary to extract knowledge from other types of representation such as elevation, section, or axonometric views, and then analyze this information further by extracting a set of rules that describes the morphological structure of the building. In addition, more morphological attributes can be extracted, such as, axiality, rhythm, and balance.

References

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[4] Yessios, C., R. Parent, W. Brown, and C. Terzidis, "Knowledge-Aided Architectural Problem Solving and Design," NSF Report DMC-8609893, June 1989, p. 12.

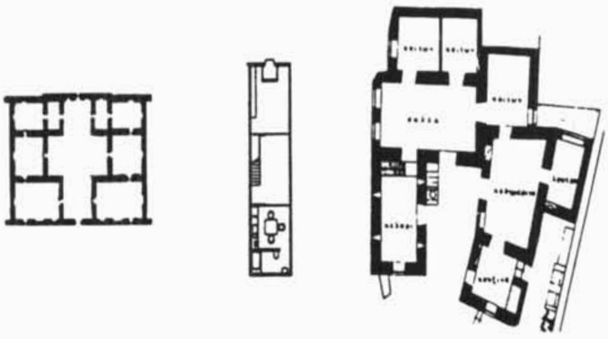

Figure 4.1: Gray-scaled Images of the Three Plans

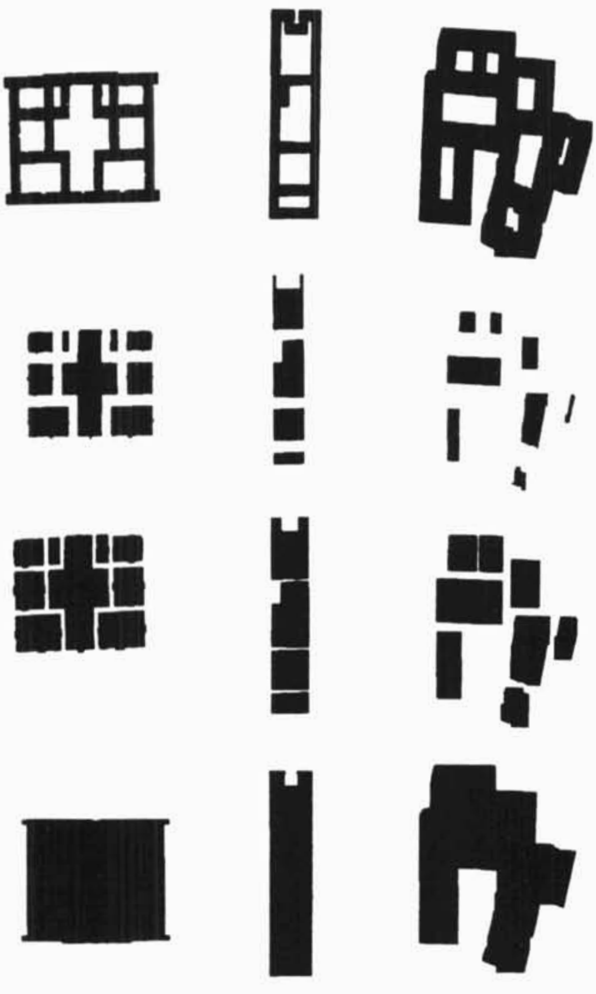

Figure 4.3: Steps in the Process of Extraction of the Geometric Structures.

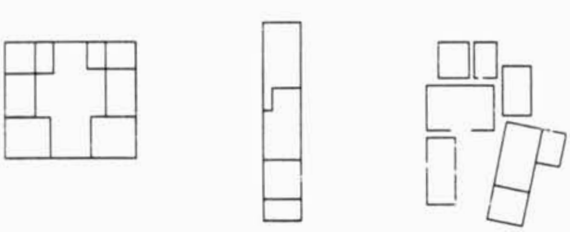

Figure 4.4: The Geometric Structures of the Plans.

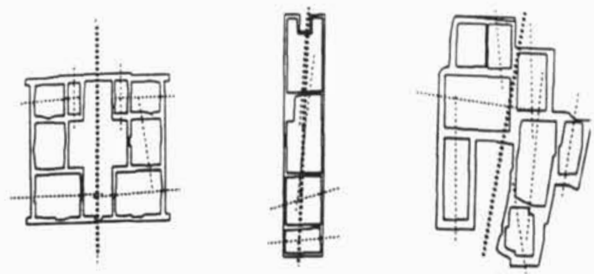

Figure 4.7: Axes of Symmetry and Lines of Orientation.

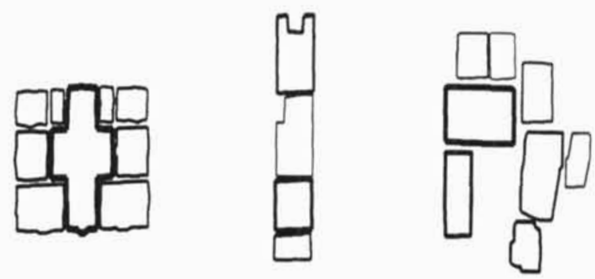

Figure 4.8: Hierarchy of Rooms According to the Number of Neighboring Rooms.

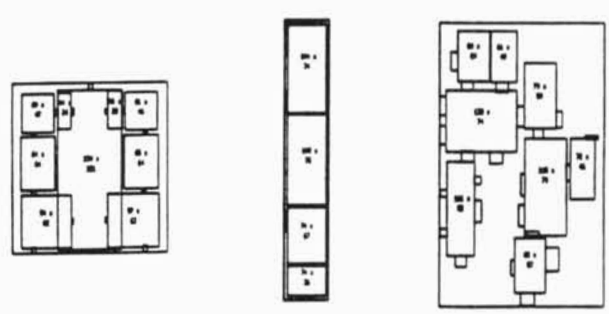

Figure 4.9: Ratios of the Sides of the Bounding Rectangle for Each Room.

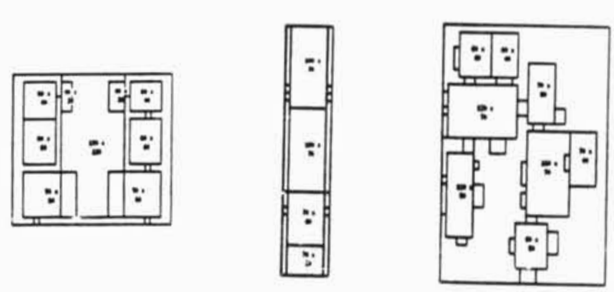

Figure 4.10: Modularity on a 10x10 Grid.