A CONCEPTUAL FRAMEWORK FOR DESIGN

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INTRODUCTION

A theoretical framework is porposed for understanding the ambiguity of architectural design objects. The framework is based on the cognitive science concept of a "semantic network" and on the artificial intelligence concept of "frames."[1] It is linked to a computer graphics rendering program. It presumes that an architect draws objects (e.g., walls) with ambiguity at the beginning of a design process. The objects take on a more specific function and form over time as the design process moves from a schematic to a more detailed sttae. The ambiguity, however, is not merely a vagueness. Rather, the ambiguity has to do with a potentially wide set of potential identities that a schematic design object may have (i.e., an object may simultaneously be identified as a kind of "wall" object, and/or a kind of "skin" object, and/or a kind of "load-bearing" object.) At the end of the deisgn process, the set of potential identities may become fewer. Yet, when the project is finished, some ambiguity may still remain. The framework for describing the ambiguity is called a "conceptual structure." This paper desribes how then conceptual structure functions and gives a few short examples from a larger set of case studies that were undertaken.

Using a computer as a research tool, a knowledge based system and a rendering program were developed. The computer tool is used to describe the material attributes and to render the visual appearance of objects. This project was initially undertaken for the author's Ph.D. dissertation in architecture.[2] The knowledge base which underlies this program is called a *conceptual structure.* The *conceptual structure* represents the architectural objects of a design project. It also represents the properties that the objects may inherit by being classified in certain ways. For example, an object may be classified as a kind of "masonry" object and may inherit some material attributes of marble, or brick, or concrete. An object may also be classified in potentially more than one way, such as an object that is simultaneously a kind of "exterior wall" object, and also a kind of "travertine marble" object, and also a kind of "load bearing" object, etc.. In addition, the *conceptual structure* can be used to describe how schematic objects may be modified in the design process. For example, the *conceptual structure* can be used to describe the transformation of a wall from a schematic massing object into a final and more materially specific object.

Each classification within a *conceptual structure* holds attributes which can be used to describe some aspects of a design object. Some of the classifications may have precedence over other classifications for certain attributes, such as color, or texture, or materiality or size or other qualities (see figure 1). The attributes in turn determine the 3D visual appearance of the object within a computer rendering. The *conceptual structure* allows potentially conflicting classifications for a design object to co-exist within a consistent framework. It suggests a way to

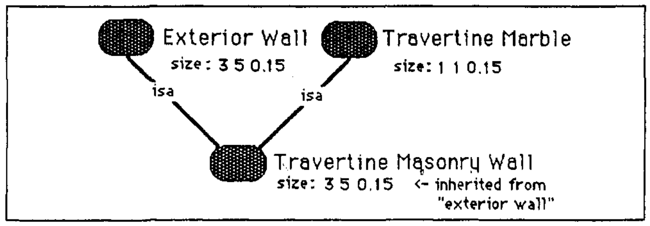

Figure 1: A "Travertine Masonry Wall" is an "Exterior Wall" and a "Travertine Marble" object

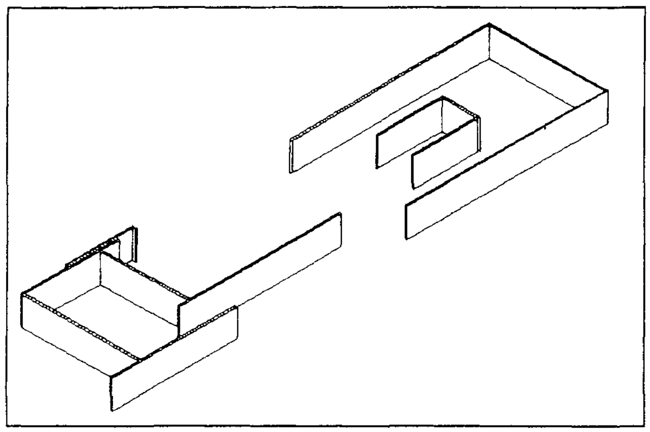

Figure 2: Stage 1 - First Sketch; screens and spaces

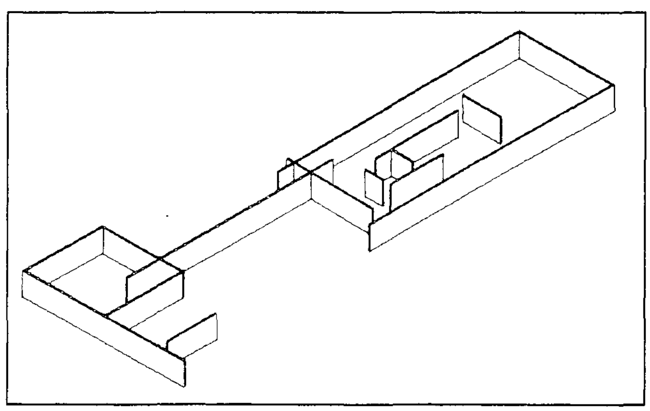

Figure 3: Stage 2 - Second Sketch; screens and spaces redefined

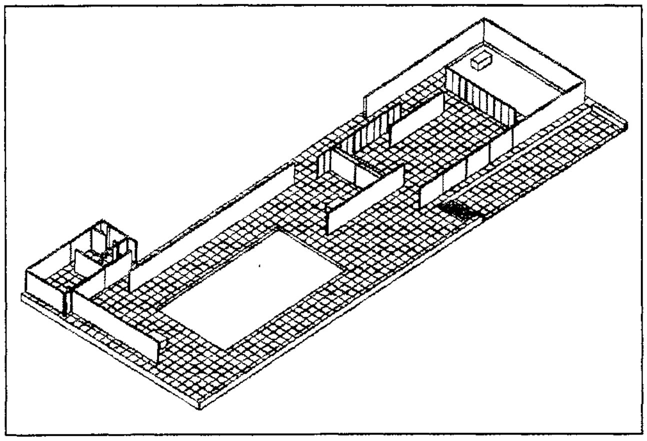

Figure 4: Stage 3 - First Draft Plan; Axial paths, exterior and interior spaces, roof omitted

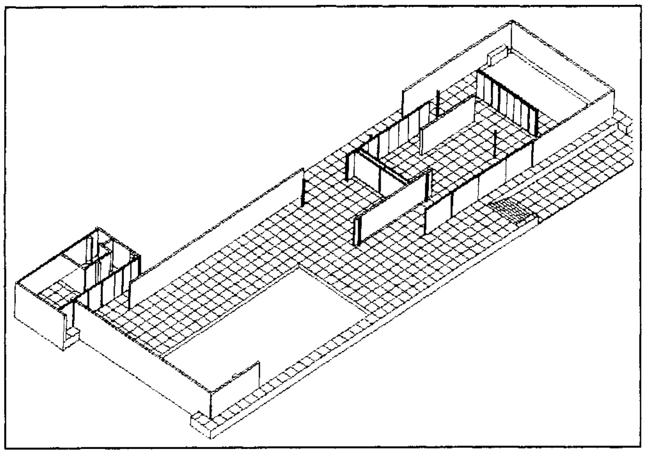

Figure 5: Stage 4 - Second Draft Plan; paths and spaces redefined, structural elements added, roof omitted

understand architectural objects as not submitting to any one exclusive determinate classification, especially as may be the case in the early phases of a design process.

A key assumption of the *conceptual structure* is that designers work by associating many potential ideas with a graphic representation. For example, an architect may associate the concept "wall" with the line drawing of a rectangle. At the early stages of the design process, the ideas associated with the rectangle drawing of the "wall" may be especially indeterminate. That is, the "wall" may be of undetermined materials, construction, elevation and structure. It may be a kind of marble wall, or a kind of brick wall, or a kind of wood frame wall, etc...It may be transparent, translucent or opaque. It may have window openings or may be solid. It may be load bearing or non-load bearing. These alternative possibilities may exist in the mind of the architect. However, the architect would not necessarily make explicit the entire range objects that the rectangle could be. A few alternatives may be implicit in the graphic representation and perhaps an associated annotation such as "wall," "load bearing wall," or even "skin."

The implicit classifications of an architectural object such as "wall" or "skin" are in this theory a critical factor in the design process. The implicit classifications for a design object may even change according to different instances of its use within the same building. For example, the columns on the front of Alberti's Facade for S. Francesco, Rimini are ornamental and not identified closely with the structure of the wall behind them.[3] They are building elements attached to the wall, but it seems not fully integrated wall elements. Yet the column pilasters on the side of the cathedral are more closely integrated within the wall, and may be thought of more directly as wall elements. Here the same kind of architectural object may submit to being classified as either "ornament" or "wall element" according to how it is used. This paper illustrates how the "conceptual structure" may be used to explain some of the ambiguity inherent in the walls and other design objects of Mies' German Pavilion.

A CHRONOLOGY OF MIES' GERMAN PAVILION

Models illustrated below in figures 2 through 6 depict Mies' German Pavilion. They are developed according on a chronological sequence of drawings by Mies' that were concurrent with different phases to the evolution of the design and on the basis of the reconstructed drawings and of several historians and critics.[4] There is the presumption that objects in Mies's German Pavilion went through a series of transformations. They transform from schematic to more detailed states. For brevity, these transformations are summarized in a series of five stages. The five stages show in turn increasingly greater specificity with respect to materiality and geometry.

OBJECT TREE FOR THE GERMAN PAVILION

The five 3D models are most closely developed after presumed major phases in the transformation of the design. This description of the evolution of the Pavilion in several stages lends itself to development of a conceptual structure. The state of any 3D model can be represented as an Object Tree. The tree indicated in figure 7 reflects the fifth stage of the pavilion. Each node within the tree represents a class of objects or a physical object in the 3D model of the pavilion. The transformations of the model from stages one through stages five can also be represented as a series of object trees. Each successive tree is refined representation of object classes and discrete objects. As will be discussed further below, the narrowing and deepening of the tree provides an interpretation of how the design for the pavilion evolved. At a more magnified view than presented in figure 7, the nodes within the tree contain information similar to that represented by figure 1 above.

The process of how objects are defined and created for the tree is too lengthy to be described in this paper. This involves the use of pop-up dialogue menus. The creation of the tree is done simultaneously to and as a part of the process of building the CAD model. The software procedures developed for this project encompasses both the automated generation of the tree and also the computer graphics engine for the CAD system. Figure 8 depicts the use of the software at a moment when an object is added to the tree and when an instance of it is placed within the CAD model (the command insert instance). The drawing of the German Pavilion in figure 8 corresponds to the object tree in figure 7.

Each tree provides a basis for speculation on what classifications of objects could have been relevant to Mies' initial development of the design for the German Pavilion. The transformation of a tree suggests how it classes of objects and discrete objects may have been redefined during the evolution of the design. Construction of the final tree was a dynamic process. There were many cases of creating objects, and of pruning, moving and extending the branches of the tree that linked the objects. A branch may be created from an object in the upper portion of the tree to an object in the lower portion of the tree. The branch signifies that one class of objects contains another class of objects, or it may signify that one class of objects contains a particular object. The object contains attributes such as materiality, roughness, smoothness, strength, etc... The values for these attributes may be inherited from an upper object to a lower along any branch or series of branches that link them.

Only two close-up snapshots of the tree are presented in this paper, figures 9 and 11 below. The first snapshot of the tree corresponds to the beginning of the development of the fifth 3D CAD (figure 9). The second snapshot of the tree corresponds to a later stage in the development of the fifth 3D CAD model (figure 11). The branches of this tree become longer and more intricate from the first version of figure 9 to the later version of figure 11. All the initial classes of objects within the tree remain intact, but inheritance of their attributes through the branches has in some cases been modified.

A CONCEPTUAL STRUCTURE OF MIES' DESIGN TRANSFORMATION

The object tree depicted in figure 9 corresponds to the fifth CAD model the German Pavilion during an early stage in its development. The CAD model itself is represented in figure 10. There is less depth and less width than in this tree than the one which is depicted in figure 7. In particular, there are fewer objects, fewer branches between "parent" classes in the upper part of the three and their "children" children classes in the lower part of the tree. The tree of figure 9 contains a more general classification of objects than the detailed final classification of figure 9. That is, not all the walls have yet been included in this version of the object tree nor represented within the corresponding CAD drawing.

Note in particular that in figure 9, the object "walls" has children objects "interior and "exterior." These objects in turn have further children objects "interior-1," "interior-2," "exterior-1," and "exterior-2." These last children are at the bottom of the tree and correspond to actual instances of these walls within the emerging computer graphics model of figure 10. Within the final tree of figure 7, however, the lines of inheritance for the final object tree have been much further expanded. The wall instances are more numerous than "interior-1," "interior-2," "exterior-1," "exterior-2."

Each of the wall instances more complete tree of figure 7 has been transformed to contain a more precise and complete description of geometry attributes. Correspondingly, the walls represented in the CAD model of figure 8 are also more detailed. The instances of the walls that appear within the model are special types of tree objects. They are the only tree objects that are visualized directly within the CAD model. They inherit all of their attributes from "parent" classes of object except for x_scale, y_scale, z_scale, rotation and origin. These attributes are defined locally and uniquely for each wall instance when they are "instantiated" within the computer graphics model.

At the top of the tree of figure 9 is "arch-obj," a nominal root object which is the parent of the tree. The next level of the tree consists of objects that represent the major classes

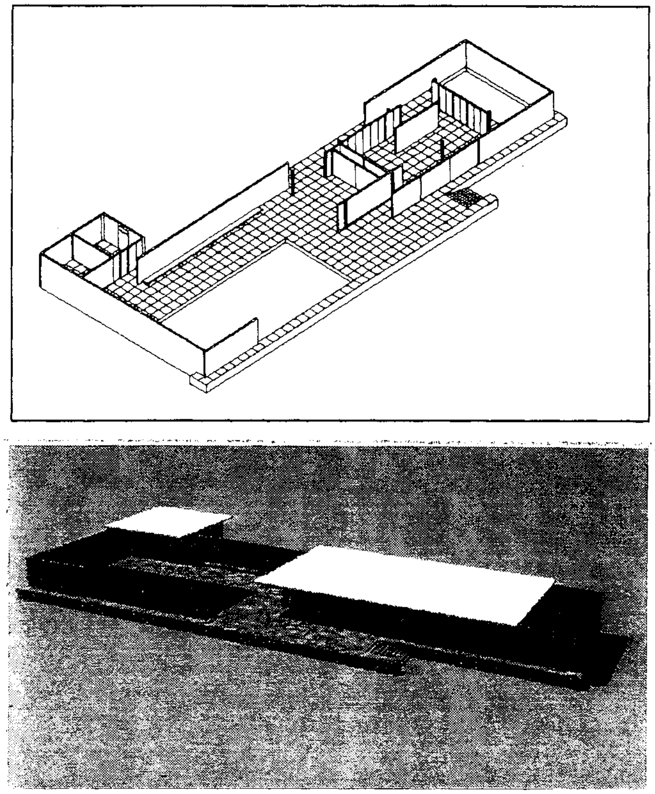

Figure 6: Stage 5 - Third Draft Plan; resolution of details, accommodation to specific architectural objects. Roof omitted. Line Drawing above and fully rendered view below

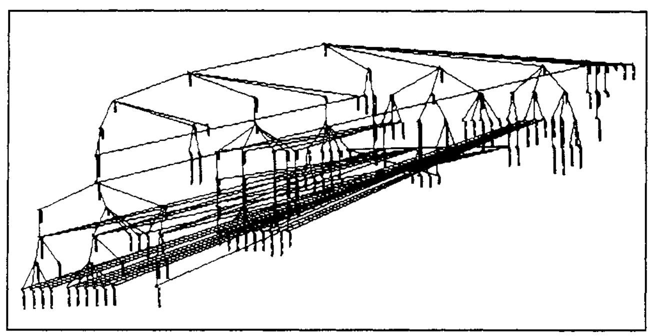

Figure 7: Object Tree for the German Pavilion

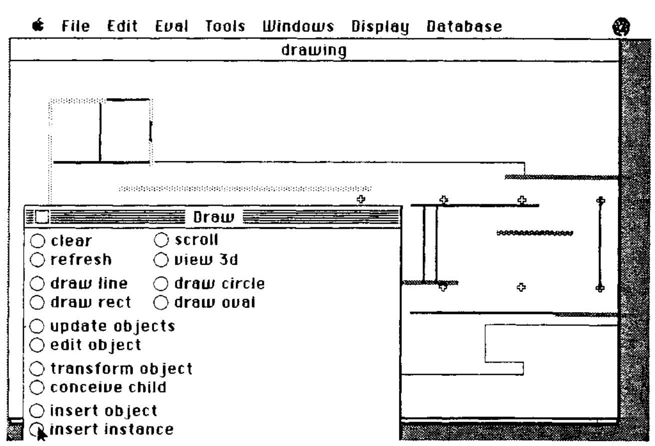

Figure 8: Creating an instance of a wall within the CAD system with a plan view of the model

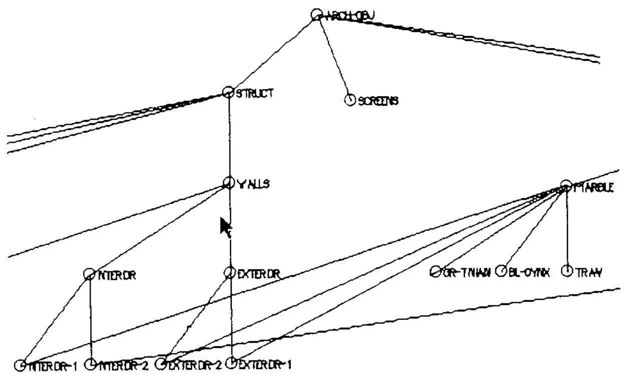

Figure 9: Snapshot of an early object tree for the fifth 3D model.

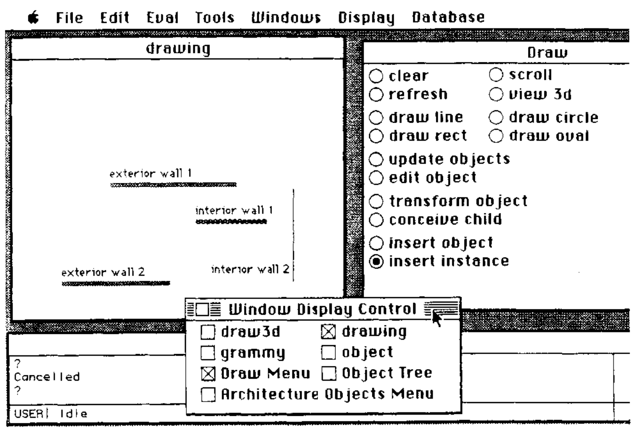

Figure 10: Preliminary representation of walls' geometry: Two exterior walls and two interior walls of Mies' German Pavilion drawing on the left-hand side of the widow below; the instantiation option is invoked in the Draw Menu at right.

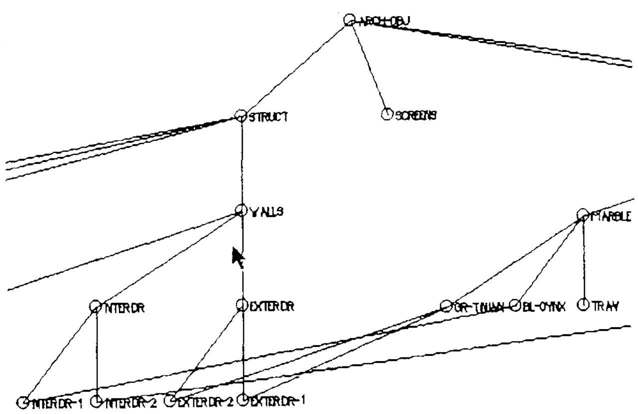

Figure 11: Snap shot of a slightly more developed tree for the German Pavilion

"struct" and "screens"(and some others such as "materiality," and "sculpture" that are not actually shown in the close-up snapshot of figure 9). The object named "struct" has children objects named "columns," "roofs," "floor" and "walls." Note that there is a major difference between this version of the tree and the final one that appears in figure 7. There are fewer nodes along any branch of this tree. There are fewer multiple links between any child and parents. There are also fewer attributes (e.g., color, roughness, specularity, etc.) associated with many of the objects on the tree, although this is not directly apparent in the graphs shown.

There are a few significant changes from figure 9 to figure 11. Figure 11 is a snapshot of the next evolution of the tree. The most prominent of the changes is related to the right side of the tree. In figure 9, the inheritance links for the walls have not yet been connected to parent objects for "green tinian," "black onyx," and "travertine" marble. Instead of these links, the wall objects "interior-1," "interior-2," "exterior-1" and "exterior-2," have so far only been connected to the more general parent class "marble." This tree would perhaps reflect the visual description of materiality evident in Mies' first sketches of the German Pavilion. In the first sketches, the walls are drawn in a shade of gray that is not representative of any particular kind of marble. The shade of gray, however, may represent an as yet undetermined or a general class of marble. Note too that the objects for "green tinian," "black onyx," and "travertine" still exist within this tree. They are materials that may exist within the emerging concept for the Pavilion at the early design stage, but they are not yet assigned to specific wall instances. In figure 11, however, the links within the tree indicate that some specific material assignments to the walls are made.

For any of the four walls shown, the material attributes might be inherited from any one of a number of "parent objects," namely the ones labeled as "gr-tinian," "bl-oynx" or "trav."

AMBIGUITY

More than one parent for a type of marble could be connected to a single wall object (this is not the case in figure 11). Figure 12 depicts a user dialogue where more than one parent is assigned to a kind of hybrid object. For example, there might be branches from both "bl-onyx" and "trav" to a child object called "trav-blonx-hybrid". The ambiguity is flagged by the computer. (The method of flagging this condition is based on the *differential search* algorithm, a technique that is beyond the scope of this paper.[5] This algorithm simply provides a means for testing the relative influence within the tree of an object's parents for a particular attribute such as color, texture, roughness or shininess.) When a material assignment needs to be ascertained for doing a rendering, the dialogue box of figure 12 flags the ambiguity. The computer program then provides a means for the user to rank order the parents according to which one should take precedent for the material attributes. Or, it is possible to select a mix of the material attributes from both parents (e.g., a mix that might have the color, texture and roughness of black onyx and the shininess of travertine).

IMPLICATIONS

The experimental CAD system depicted in this paper suggests that ambiguity may be provided for within an explicit architectural description. In a preliminary design phase, objects may have some attributes fully determined, others more variable within a limited range, and still others left completely uncertain. These attributes are inherited from "parent" classes. The "parent" classes suggested in the example above, such as "walls," "marble" and "struct" are conservative. An object tree might include the parent class "wind", and its attributes inherited by child class "water". Through the branches that connect "water" to instances of it in the German Pavilion, the attribute of "force" may be inherited. The two reflecting pools in the German

Pavilion are object instances of water. In turn, the inherited attribute "force" may travel through the branches of the tree and cause the instances of water to formally respond by generating waves (see the waves in the reflecting pool depicted in figure 6). The CAD system that does not recognize this range of alternative conditions and relations is weaker at representing the knowledge base an architect draws upon when making design decisions. This alternative CAD system attempts to make explicit certain conditions of ambiguity that are typically not represented.

The object tree provides for a way to think about architectural objects as not inhabiting a finite world of fixed and highly determined descriptions. Classifications of objects and attributes which they infer can shift over the life span of a project. Such a system could be used to view existing and already built works of architecture within framework of historical analysis and criticism. For example, this historical reconstruction of the German Pavilion is very speculative about relationships and classification hierarchies.

The more significant conjecture about architecture underlying this system is that design is not about concrete objects that are fixed in their meaning with respect to higher lever classification concepts. This system operates under the assumption that design is influenced by many closely and distantly associated classifications of objects. The precedence of some classifications over others may shift according to different frameworks of analysis. The conceptual structure provides a basis for diagramming many relationships which are not always visually made explicit in the rendering of a building at the same time. It is possible to visualize works of architecture where one set of formal descriptions may predominate without being exclusive.

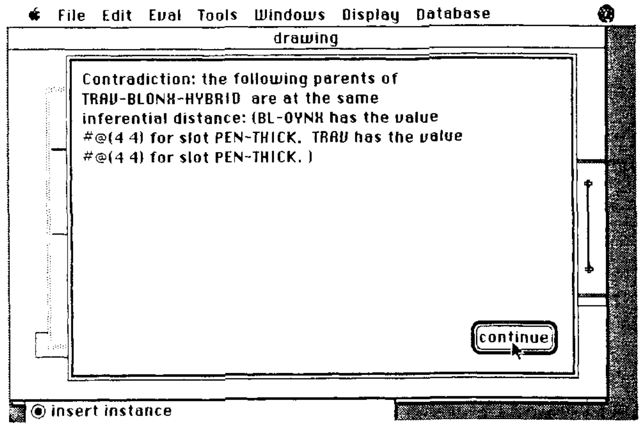

Figure 12: Ambiguity flagged by the differential search algorithm. The object tree serves as a means to filter the CAD model visually at different levels of abstraction. Its possible to point to a object class in the tree for transparent walls and direct the system to draw only those walls that inherit attributes from it, or to point to another object class in the tree and view only those walls that are opaque, or to visualize the model according to some other criterion. The images depicted in figure 13 have been generated by the CAD system this way.[6]

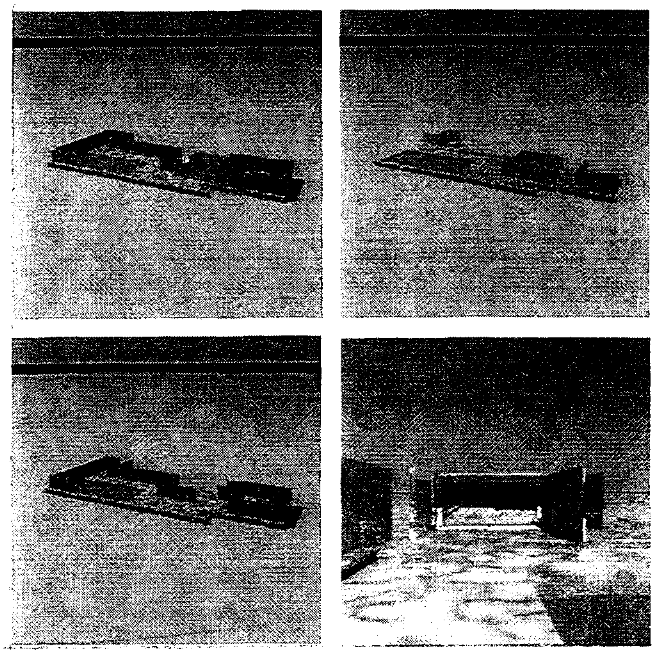

Figure 13: Filtering the CAD model by selecting different classes of objects represented on the object tree.

NOTES

1. The conceptual structure is based on the cognitive science concept of a semantic network and on the artificial intelligence concept of frames. These concepts are not developed in the paper, but the interested reader may be referred to Minsky, Marvin. *Society of Mind.* (Cambridge, MA: MIT Press, 1987).
2. Mark, Earl, *Conceptual Structure: A multiple-inheritance classification and design system.* Ph. D. Dissertation, Harvard University, November 1993.
3. Wittkower, Rudolf, *Architectural Principles in the Age of Humanism.* (London: Alec Tiranti Ltd., 1952). Copyright permission is needed to use photograph.
4. These critiques include Bonta, Juan Pablo, *An Anatomy of Architectural Interpretation.* (Barcelona: Editorial Gustavo Gill, S.A., 1975). Carter, Peter, *Mies van der Rohe at Work.* (New York: Praeger Publishers, 1974). El Pavelló Almany de Barcelona de Mies van der Rohe. Fundació Pública del Pavelló Alemany de Barcelona de Mies van der Rohe, Ajuntament de Barcelona, 1987. Johnson, Philip C., *Mies van der Rohe.* (New York: The Museum of Modern Art, Third Edition, 1978). *Mies Reconsidered: His Career, Legacy and Disciples.* (Organized by John Zukowsky) (Illinois: The Art Institute of Chicago, 1986)
5. For a discussion of this algorithm, see Rich, Elaine, and Knight, Kevin, *Artificial Intelligence.*(New York: McGraw-Hill, Inc., 2nd Edition, 1991)
6. This involved writing several translators, where the geometry of the experimental 3D CAD system was translated into an AutoCAD file, and where that geometry was then translated into the Radiance 2.0 raytracing environment. This was handle as a batch file process. The translators were developed by the author working off the efforts of several others. Radiance is developed by Greg Ward of Lawrence Livermore Laboratory.