An Online Catalogue of Virtual Reality-Based Morphological Analyses

LEONARD MICHAEL TEMKO
EMMANUEL-GEORGE VAKALO, Ph.D.
University of Michigan

INTRODUCTION

This paper discusses several issues related to the study of the morphological structure of architectural precedents. We suggest that there are areas of design consideration that exist outside of the clearly demarcated constraints of function and that morphological analysis of significant buildings is one way in which students can gain needed exposure to the more formal aspect of building. In addition, we examine methods of representation and the possible problems of perception and question if traditional methods of architectural representation alone are enough to transmit the amount of spatial information required for a more complete understanding of built form. Finally, we suggest that recent developments in virtual reality technologies enable the possibility of an architectural representation that is widely accessible as well as cognizant of the problematic dimension of time that is of such importance to the perception of architectural form. This final point regarding virtual reality representation serves as the basis for an ongoing research effort that promotes virtual reality technologies for the online presentation of the morphological analysis of historical precedents to the student of design.

THE MORPHOLOGY OF ARCHITECTURE

The case for the study of the morphological structure of architectural precedents is found in the notion that there are areas of inquiry in design that exists outside the realm of function. This undefined component of the design process serves to ease the natural tension caused by the architect's need for "something stable and universal -a basis for prediction and recognition, and the need for personal and emotional identification" (Thiis-Evensen, 1987). Thiis-Evensen recognizes that the building design process is more than a rational problem-solving exercise. According to him, it is also an opportunity for creative expression. The difficulty for the student of architecture lies not in grasping that there are opportunities for expression unmolested by functional requirements, but rather in understanding when it is appropriate to exploit them (Krier, 1988). To be certain, we are not advocating that irrational or intuitive design intentions are of supreme importance in the design process. It should be clear that the student recognizes that "hard" and "soft" criteria are judged in concert during the design process. What exactly informs this, as yet unconditioned, body of knowledge from which students will draw is also unclear. For the purpose of this paper we suggest that the study of the morphological structure of significant buildings is an appropriate place to start.

PRECEDENT

In architecture, the value of precedents lies in part in the belief that by understanding the past we make better decisions in the present. Clark and Pause (1996, p.vii) suggest:

> "Our concern is for a continuous tradition that makes the past part of the present. We do not wish to aid the repetition or revival of style whether in whole or in part. Rather, by a conscious sense of precedent that identifies patterns and themes, we hope to pursue archetypal ideas that might aid in the generation of architectural form."

We hope that through rigorous study of significant buildings an understanding of their underlying morphological structure will help students of architecture gain a contextual framework from which to cast their own work. Colquhoun suggests the notion of a framework when he argues that an understanding of typological precedent can significantly enhance the design process. With respect to the investigation of typological precedent he states that:

> "A certain scientific detachment towards our problems is essential, and with it the application of the mathematical tools proper to our culture. But these tools are unable to give us a ready-made solution to our problems. They only provide the framework, the context within which we operate." (Colquhoun, p.405).

This framework of understanding is of high value in those indeterminate zones of problem-solving that transcend the building's program.

MORPHOLOGY

We believe that specific formal aspects of significant buildings should be scrutinized. Architecture, like other artistic media, is commonly thought of as a communicative medium. The syntax of architecture, those elemental arrangements that form the building, have embedded in them meaning which can be communicated at a level beyond the spoken word (Ching, 1979). This, in part, may be one of the strongest links of architecture to the other visual arts. Verbal description of a painting, sculpture, or building will not carry the same meaning as actually seeing them first hand. (Baker, 1996). This is not to say that well constructed verbal descriptions are of no use or are not meaningful but rather that they are limited to the viewpoint of their creator. Architectural photography, for example, is often considered a manipulative medium.

In a similar vein, the morphological structure of architecture is analogous to the grammatical structure of natural language. If words, sentences, and paragraphs and the rules that govern their composition are the morphological structures of the novel or short story (Ching, 1979), then the same is perhaps true of the walls, floors, and columns, and the rules that govern their composition in architecture. Students learn grammatical rules, definitions of words, and proper sentence structure in part by observing each component outside of its natural context. The same methodology can be applied to architecture. That is, architecture can be analyzed in terms of its component morphological elements outside of their natural context. Arguably, there is much to be gained by doing so.

METHOD OF MORPHOLOGICAL ANALYSIS

Traditionally, the morphological analysis of buildings was accomplished through a careful process of graphical representation. Morphological information can be shown in plan, section, elevation, and in three-dimensional drawings, diagrams, or photographs. Individual morphological components are identified and diagrammed, usually separately, in an abstracted way in an attempt to understand the nature of the building (Clark & M. Pause, 1996). When more than one building is analyzed along these lines the students can begin to compare the use of specific elements between buildings and thus begin to see how the use of similar elements in different situations can lead to many different possibilities. This process of analysis provides valuable insight into the principles, concepts, and rules underlying the derivation of architectural form as well as a better understanding of the relations of the part to the whole. Of the many individual elements that can be abstracted from a building, the following are most commonly diagrammed:

-Horizontal Planes (degree of enclosure)
-Vertical Planes (degree of enclosure)
-Structure
-Openings (connection of in and out)
-Penetrations (vertical connection)
-Path (circulation)
-Indeterminate Zones (in or out)
-Additive and Subtractive Forms
-Organizing Grids
-Light and Shadow

This list, by no means complete, is a summary of common analysis information as presented by Ching (1979) and Baker (1996), both of whom offer comprehensive discussions of the different formal categorizations. Our interest in the study of architectural morphology, however, has uncovered an interesting paradox. That is, the purpose of the analysis of buildings is to identify formal patterns that illuminate the possible rules that led to the building's creation. However, buildings are spatial constructs and our experience of them relies on our ability to perceive those qualities that make them spatial. Analysis, then, must be at least as concerned with the spatial quality of the object as well as its geometry. Yet, of the types of representation mentioned earlier, all but photography are absolute abstractions of the subject and represent views of the world that are either not possible or highly unlikely (Zevi, 1993). The traditional methods of representation that have supported morphological analysis are limited in their ability to transmit spatial information to those employing them and thus only give a partial picture.

REPRESENTATION AND PERCEPTION

The notion that traditional methods of representation, for any artistic endeavor, provide an efficient means for the transfer of critical information inherent to the nature of the object is arguable. It is not likely, for example, that a representation, a photograph perhaps, of a significant painting will do justice to or provide the same level of stimulus as the original. The same can be said of sculpture, perhaps more so, because of its multidimensionality and reliance on time in the act of observation. Even recorded music, in this day of high fidelity digital recording is often thought to have lost something in the transfer from the performance to the disk. We must ask, then, what is the essential property that is missing in representation that prevents us from gaining a full appreciation of the object? We think that a possible answer can be found in the literature concerned with perception.

Perception is generally regarded as a cognitive process that relies on the formation of internal representations within the brain. These representations are associative, persistent, and form the basis of thought (Kaplan, 1983). The connections between the internal representation and the stimuli that it represents are also thought to be physical (Schwartz, 1998). Phenomena of the world, or external stimuli, can be thought of as the cues that help us form our perceptions. It is important to note here that internal representations are not complete, mirror copies of the real world objects but are more like internal structures that contain references to identifying parts (features) of the object (Hebb, 1980). For example, when one sees a cat, the structure that represents cat in the mind is made up of features that represent triangular nose, and ears, long tail, furry, etc. In other words, these cognitive structures are very good approximations of the object, not the object. An interesting quality of internal representations, or structures, is that they are predictive. If enough features are recognized from external stimuli, the entire structure "lights up" and we perceive "cat." This is important because it means that given conflicting or insufficient stimuli our ability to perceive is not short-circuited. We may misperceive on occasion but the mind is always able to make a guess (Hebb, 1980). Our ability to arrive at a perception given incomplete or confounded stimuli is profound when it comes to spatial perception.

SPATIAL PERCEPTION

The perception of space depends heavily on a person's ability to perceive specific visual cues, and these can either be static, dynamic, or physiological (Prak, 1977). Static cues are those that aid in our understanding of stationary scenes, such as a photograph, and can include color differentiation (tonal and shading differences), interposition (larger and smaller sizes denote distance from the eye) and perspective foreshortening (parallel lines converge at a distance). The dynamic cue, motion parallax (object relations change with point of view) aids in our understanding of scenes that are fluid or contain movement. The physiological cues of stereopsis (stereoscopic vision), accommodation (focus at a distance), and convergence (eyes adjust for close objects) aid in our ability to perceive depth (Prak, 1977). There are of course other cues, those associated with the other sense organs (ears, nose, etc.) that also affect how we perceive space but for the purposes of this paper we are focussing on those cues that affect sight. Of the perception cues mentioned above, static cues are all accommodated, with varying degrees of success, in traditional representation with photography representing the most successful in terms of the number of cues presented. The dynamic and physiological cues, motion and stereopsis, however, are more difficult to reproduce mechanically.

Perception, as mentioned above, is affected in large part by our experience in the world. It is also suggested that diversity of experience also helps the mind build more complete internal representations (Bruner & J.M. Anglin, 1973). What makes spatial perception so complex, and extraordinary, is that the spatial world is so variegated. The addition of motion, or time, suggests that the number of potential perspectives for processing is infinite. Thiis-Evensen suggests that the acts of motion, walking, running, turning, and even sitting (we are never really still), are not inconsequential to our ability to perceive spatially (Thiis-Evensen, 1987). As we move through space, our position relative to many different objects is in constant flux and none are consistent with each other. Thus, the notion of path becomes extremely important to our understanding of space. Zevi suggests:

> "Space in actuality is grasped through an infinite number of paths. Moreover, it is one thing to be seated in a comfortable seat in a comfortable theatre and watch actors performing; it is quite another to act for oneself on the stage of life. It is the same difference that exists between dancing and watching people dance, taking part in sport and merely being a spectator, between making love and reading love stories. There is a physical and dynamic element grasping and evoking the fourth dimension through ones own movement through space" (Zevi, p.59).

So, even more recent highly realistic computer generated images are no better than photography when it comes to representation. The next logical step, the computer generated animation is also limited by the fact that the path (camera) is typically scripted and singular. The viewer sees the object from the perspective and timeframe of the designer. The viewer rarely has a choice in the matter. Finally, there is the problem of familiarity. That is, people experience architecture every day. People live their lives in and around buildings to an extent that the built environment becomes something akin to background information. This is not to say that we do not notice the buildings but that our ability to process the information generated by the special qualities of space approaches the level of intuitiveness. In our view, this intimate familiarity with the subject matter makes us much more difficult to fool. Consequently, the attributes chosen for representation must be carefully considered.

VIRTUAL REALITY AS A REPRESENTATIONAL MEDIUM

The rapid escalation of processing power coupled with falling hardware costs has led to the development of new and exciting computer-based technologies. Of particular interest to architectural practitioners and academics alike is the development of virtual reality as a stable and readily available platform for the representation of architectural objects. It is our view that the development of virtual reality as a representative medium is no less important or significant than the development of perspective projection during the Renaissance. Virtual reality's core function of allowing free-range of motion and user control represents a major break from traditional computer-based photorealistic imaging. While photorealistic images may be convincing to some degree, the research on perception seems to indicate that other criteria are more critical to our ability to perceive spatially, specifically, those of motion, stereopsis, and convergence. Our ability to "fill in the blanks" is quite acute because perception draws on our pre-existing cognitive maps and internal representations, which are defined by our experience in the world. Photorealism is not always necessary as long as there are other sufficient cues to aid us.

VIRTUAL REALITY (VR)

Technologies that describe VR can be grouped into four categories: text-based, non-immersive, immersive, and hybrid. Text-based virtual reality systems are of three types: MUD's (multi-user domains), MOO's (Mud's, object oriented), and MUSH's (multi-user, shared hallucination). All are free-form narrative constructions that exist largely on the Internet and require each user to participate in a non-linear dialogue by typing and reading responses on a computer screen. While not originally considered true VR, these text-based systems often use a spatial metaphor that stimulates an imaginative and, sometimes, a sensory perceptive experience.

Non-Immersive virtual reality systems, also known as monitor-based systems, are non-stereoscopic visual simulations typically viewed on a computer monitor. As such, they do not require the use of shutter glasses or motion tracking in the process. Virtual Reality Modeling Language (VRML) models describe three-dimensional geometry that can be rendered on a computer screen in real-time. The models are navigable, can be enhanced with material mapping, sounds and animations and can be distributed over the Internet and viewed with special browser plug-ins. Apple's QuickTime VR and Live Picture's FlashPix are related technologies that allow computer generated or real images to be "stitched" together in a panoramic format. While the user can pan, dolly, and tilt a camera to change the viewpoint, navigation is limited to a fixed point. This lack of free-range navigation limits the number and type of visual cues that can be transmitted. In contrast, VRML allows for free-range navigation and thus can accommodate many of the important static and dynamic cues necessary for true spatial perception.

Immersive virtual reality systems comprise the most varied and expensive group of VR technologies. Immersive VR systems usually require the use of shutter glasses or small head-mounted CRT (cathode ray tube) screens, project true full-scale, stereoscopic images, and incorporate motion-tracking for reference and position in the VR scene. These include Head-Mounted Displays (HMD), Head-Coupled Displays (HCD), Fakespace's BOOM device, Table Projection Systems (ImmersaDesk, Responsive Workbench), and the CAVE (Cave Automatic Virtual Environment). Because these systems are able to display full scale, stereoscopic images that appear to surround the user (and in the case of the CAVE actually do surround the user), the simulation is considered to be the most spatially believable. Immersive virtual reality can accommodate most of the static, dynamic and physiological cues necessary for true spatial perception.

Hybrid virtual reality systems combine one or several of the above configurations. These include Large Screen Projection Systems (EVL's Infinity Wall, SGI's Power Wall) and Augmented Reality (AU). The large screen systems are often projected on what appears to be a tabletop or a rear projected television with a curved screen. AU systems combine stereoscopic projection of VR geometry or information over live or natural views through special optical or video displays and employ motion-tracking to aid image registration. Unlike VR which seeks to recreate the "real world" through representation, AU is intended to supplement or overlay virtual reality information over real world views; usually in the aid of some action or task (Mahoney, 1999). AU's viability, however, continues to be illusive because of difficulties in registration and tracking (digital to real) and hardware size but it is still an exciting and promising research area.

The category of virtual reality technology chosen for this research project is non-immersive and uses web-based VRML models in a standard HTML framework. VRML is a low-cost, functional, and exciting way to view architectural representations. VRML can display static and active visual cues (as well as auditory ones), and the ability to view the models created in this standard is free to anyone with a computer and a browser plug-in, which itself is also free and supported on multiple platforms. While fully immersive environments represent the "Holy Grail" of virtual reality representation, we feel that VRML is an effective compromise and is positioned for broad acceptance.

THE ONLINE CATALOG

The Online Catalog is conceived with two goals in mind: The creation of a widely available VR-based catalogue of significant architectural precedents for use in an instructional setting.

To provide interactive morphology-based models that will aid the student, or anyone interested in built form, in the comprehension of abstract spatial information.

There are currently two houses accessible on the Internet, LeCorbusier's Villa Savoye (1929-31) and Rietveld's Schröder-Schräder House (1924). We plan to produce other representations of buildings by Mario Botta, Peter Eisenman, Raphael Moneo, Tadao Ando, and Andrea Palladio. In the end we hope to have a large set of buildings that span a significant period of time and styles. The virtual reality environments are structured around a series of user interactions and viewpoints. In their initial state, the building is illustrated in its totality. The user can choose from several predefined viewpoints or can immediately begin exploring the exterior or interior of the building by "walking/flying" in and around the model. "Gravity" is always on (unless the user turns it off) so that when the user's position is over a horizontal surface, the viewpoint is automatically adjusted to approximately eye-level ((1.5m). A series of buttons at the bottom of the frame control the visibility of the different morphological categories. Each category can be viewed independently or in any combination with another category. Because the building is initially fully represented, it should be turned off prior to turning on its morphological components. Otherwise, the building will obscure some of the analytical information. We have included, when necessary, interior furnishings (beds, tables, etc) within the fully represented model so that the user receives relative size information while navigating inside. These miscellaneous objects are not visible when the morphological elements are visible.

Averaging around eight thousand polygons, the models fall within the ten thousand polygon limit that is generally considered a threshold for effective VRML presentation. Colors have been used instead of texture mapping to conserve the video-processing load. We used Autodesk's AutoCad Release 14(for the creation of the principal geometry and then imported the geometry into Kinetix's 3D Studio Max(for the placement of lighting, cameras, and basic color. The model was then exported to VRML 97 and the functionality of the application was created through the use of VRML scripts and functions.

To compartmentalize the process, the geometry for each morphological category is created as a separate model, as is the overall building. The actual VRML application framework consists of only lighting, navigation, and interaction scripts. Buttons are created and assigned touch and time sensors that are linked to each morphological model for the purposes of calling the appropriate information. The geometry for each specific category is inserted ("inlined") into the overall framework when its specific function is called. The resulting interactive representational model is finally stored on a hosting server and is accessible to anyone with access to the Internet.

PEDAGOGICAL IMPLICATIONS

Given the exploratory nature of this research, the implications of this new representational method are necessarily speculative. We suspect that students who spend time with the models and explore the different possibilities for analysis will gain significant insight into how the represented buildings are constructed physically as well as in the abstract formal sense. We hope that the student will also gain useful spatial experience of important buildings that might otherwise be out of reach for most. We think of these models as exemplars, which will help prepare the student for the traditional, and useful, task of creating paper-based morphological analyses of other significant buildings. It is not clear to us whether there is an advantage to having the students create their own computer-based models with VRML interactions. While one could make the leap that perhaps this is inevitable some time in the future, for now it seems a remote benefit given the experience required to build digital models of complex buildings. Even thought the tools for creation are readily available and the level of computer competency of students is rising, there are still reasons to continue traditional practices. We still believe that drawing, especially for the young student of architecture, is an important skill to master. The abstract nature of the exercise and the medium is also of some benefit to the student. Learning how to extract specific information from a set of drawings or, more abstractly, a small diagram in a book and then reproduce them at a larger size is of extreme importance for the architectural practitioner.

We are suggesting that the use of a representative medium that accommodates spatial information for the presentation of the morphological structure of architectural precedent will help condition the student of architecture to be receptive to the subtleties of formal and spatial qualities inherent to the medium of architecture. We believe that once conditioned, the student will be able to perceive possible patterns and relations and will be able to apply their understanding to their own designs more thoughtfully.

CONCLUSION

We have presented an argument for the use of a non-traditional medium of representation in the communication and study of the morphological structure of architectural precedent. We began by discussing the importance of precedent in architecture. We suggested that traditional methods of representation present abstract views of the world and are inherently limited in their ability to accommodate spatial cues. Spatial cues are important in the search for patterns and spatial relations. The complexity of our internal ability to represent and, thus, perceive spatial constructs, as well as our intrinsic familiarity with the subject matter makes the question of an appropriate representational medium difficult to answer.

Virtual reality, however, offers the possibility for a new way of representing spatial constructs because of its ability to accommodate some of the specific passive, active, and physiological visual cues that are required for spatial perception. Because perception is based on internal representations that are far more detailed than any mechanically created representation, we suggest that the mind is able to "fill in the blanks" when presented with less detailed models, thus suggesting that photo-realism may not be a strong requirement for the medium.

Finally, we describe an ongoing research project that involves the use of virtual reality technology as an instructional tool for the presentation of architectural precedent and morphological analysis. Used in conjunction with traditional pedagogical and representational methods, VRML may help the student of built form grasp the abstract concepts of form generation more readily.

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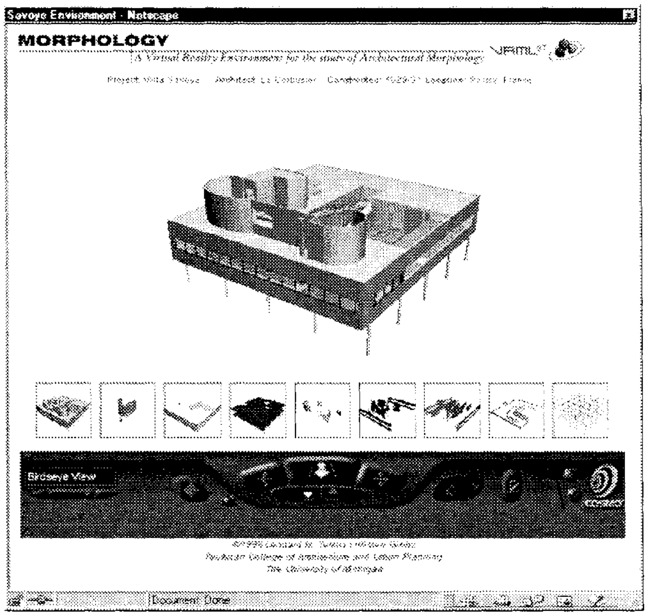
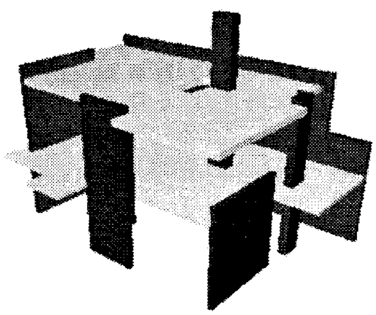
An Online Catalogue of Virtual Reality-Based Morphological Analyses Screen Shots

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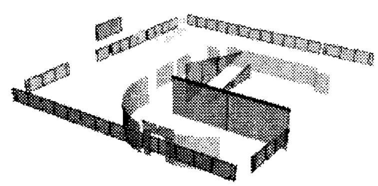
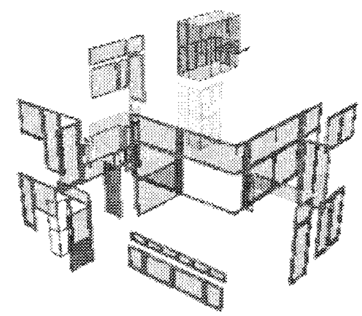

Savoye Windows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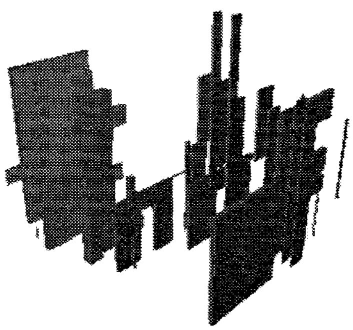
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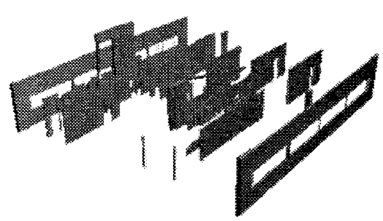
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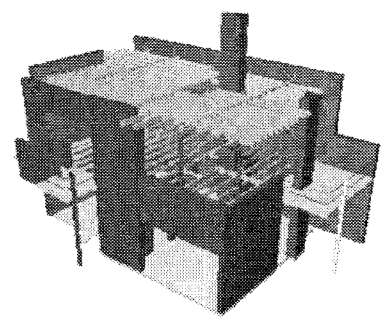
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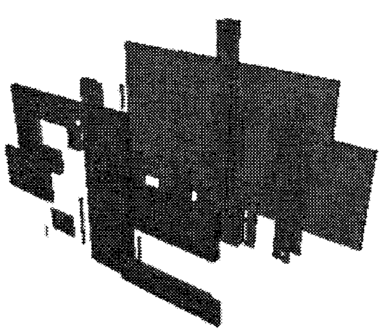
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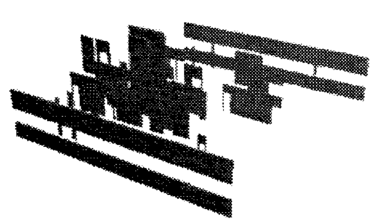
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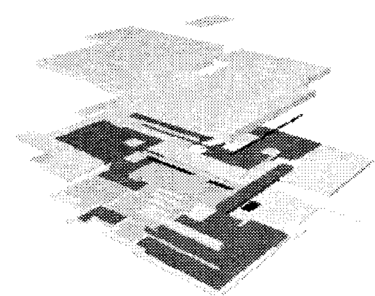
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