The Space Re-Actor

Walking a Synthetic Man through Architectural Space

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Abstract: This paper proposes a computational method for visualizing animated human reactions to physical conditions that are described in a synthetic architectural model. Its goal is to add a sense of place to the geometry, and augment the representation of its spatial quality for designers and audience. Spatial qualities in architectural design cannot be fully evaluated solely by observing geometrical constructs without reference to inhabitants placed inside. However, imagining what happens to those inhabitants and appreciating their movement is difficult even for trained architects. The proposed method introduces a walking scale figure in a geometric model. Through agent-based computation, it moves inside the model and displays various behaviors in reaction to spatial characteristics such as transparent surface, opaque surface, perforation and furniture. This method lays a foundation for developing a new kind of software that overcomes the shortcomings of current design tools.

Keywords: Architectural Visualization; Agent-based Computation;

Introduction:

As architectural projects become increasingly more complex in their formal manifestation and functional requirements, new methods are sought to address the complexities caused by multiple usages and constraints involved with them. Contemporary designs by today's leading architects are often filled with their signature expressions, and some of their design decisions seem to be executed based on their individual sensitivities and intuitions. Architects tend to underestimate the importance of the role of people inside their buildings; they are often not fully aware of the behaviors induced by the spaces which they design. The existing analytical means of architectural representations – plans, sections, elevations, axonometric, and perspective – are not sufficiently capable of visualizing the psychological behaviors of people. Furthermore, today's advanced computational design tools can produce complex forms and sophisticated visualization of light, material and geometry, but they are not suitable in helping people to quickly study and understand a spatial design that is inhabited.

Figure 1. An alternative representational tool (left). Mies at work on his scale model (Werner, 1999).

In architecture, many spatial problems are indeterministic. Solutions to particular design problems are usually constrained by multiple criteria and are far from obvious. Normally, architectural design has multiple evaluation factors, and this fact prevents it from having simple straightforward equations or methods to reach solutions. Moreover, this ambiguity and invisibility of spatial qualities tends to hide the actual problems from designers' eyes. Aesthetic values may scarcely ever be quantified or objectively evaluated, but even mere functional aspects of architecture are hard to evaluate. For instance, architectural codes respond to constituent parts of dimensional constraint in architectural spaces. However, for a building as a whole, whether or not the end products of assembly of all locally constrained parts are efficient and comfortable, are very difficult to predict before actual user involvement. A "walking actual human" on full-scale mock-up can be one solution to check the level of comfort in architecture although time and cost that it takes to execute it is considerable. Another possible approach can be using a synthetic figure based on human behavioral patterns to test the performance of space before realization of the physical space.

The paper seeks to find a tool with which to capture human reactions in architectural spaces in an animated format. By suggesting another layer of architectural quality hidden behind the constructive forms, this paper aims to bring the designers' attention back to a man on the stage, and the eyes of a user. By walking a synthetic figure through architectural space, this tool will visualize the psychological response to architectural elements in motion.

This tool differs from conventional static spatial representations because of its four dimensional qualities. While the scale-ness in 3-D space can present the physical size of objects described in x, y, and z coordinate systems, the scale-ness in 4-D can present the speed of objects in motion (along the time axis). This quality which is typically seen in cinematic representations offers several obvious advantages. As soon as we have actors on stage sets, conversation will start, which evokes a sense of physical scale to a space and depth in front of our eyes. Ability to render the event in motion is one of the unique advantages in cinema. The camera works in films are mostly driven by the events that occur in the scene and help us to emotionally connect ourselves to the events in the scenes. These emotional projections possibly alter our stance from observers to participants of the scene. This virtual layer of objectivity latent in cinematography can be a great potential representational method for any other creative activities. There is so much architects can do with formal manipulations, but too much obsession with this formality often leads architects to forget the protagonists of the spaces – people, whom they are designing for. Just by observing the forms with any existing methods, it is extremely hard to tell whether their designed components actually contribute to the performance and use of the buildings or not.

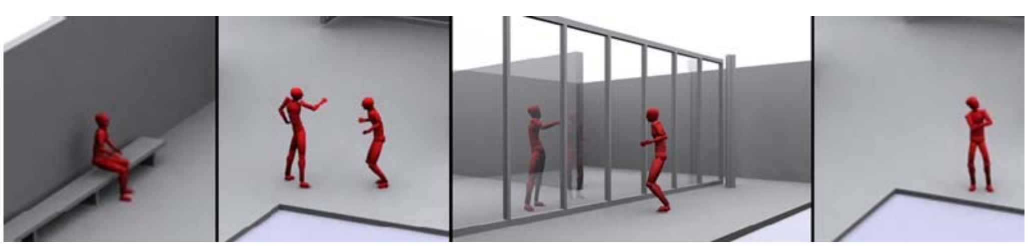

Figure 2. Re-Actions to Architectural Elements. Interactions among Agents.

Another difference between conventional architectural representations and this tool lies in the presence of autonomous behaviors embedded in the figures. Through agent-based computation, it moves inside the model and displays various behaviors in reaction to spatial characteristics such as transparent surface, opaque surface, perforation and furniture. Typically all the figures in architectural animations are controlled, prepared, and inserted afterward, on top of their 3D models in a top-down manner. For example, most of the walking figures merely follow the paths that were drawn and reinterpreted by the designer on their 3D models, and their motions are post-rationalized by the creator (animator) of the presentations. There are some levels of discontinuity between the motions of the figures and their surrounding architectural environments since they are results of reinterpretations by the observers who reside outside the environments. This new tool attempts to omit this final tweaking process by according some level of cognition to these figures from the outset of the process. These cognitive capabilities include collision detection, obstacle (walls, etc.) detection, cognition among others, and cognition of the attractions in architectural environments. Re-Action to the architectural spaces, including the reaction to the different materiality of the architectural elements, is the most unique features implemented in this tool. Since these cognitions are directly embedded in the figures on the stage sets, these reactions are directly derived from the architectural spatial conditions around them, and not from the re-interpretation or the post-rationalization.

Methodology:

The proposed method uses two platforms; the agent-based environment which computes the behaviors of each figure, and the 3-D visualization environment inside a rendering application. Results from the agent-based computation of the Space Re-Actor will define all the behaviors and movements of the figures. In other words, all the intelligence about the autonomous behaviors is acquired from the simulation program developed by the author in the programming environment in NetLogo (Wilensky, 1999.) In order to achieve physical three dimensional qualities in representation, all these behavioral information will be once translated (encoded) into text files to export the information into superior external visualization environment. 3d Studio Max release 8 is selected for the final visual representational platform due to its high-end rendering capabilities, and its availability among the architects and students. Furthermore 3d Studio Max release 8 comes with CharacterStudio which provides standard bipedal character skeletons. This biped figure is used as an actor inside the Space Re-Actor's environment based on the results acquired form the agent-based computation.

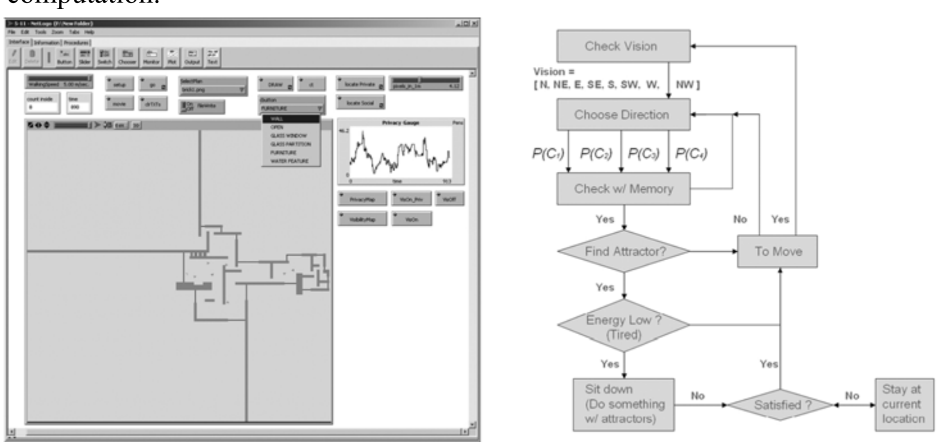

Figure 3. State Transition diagram (right) Agent-based Computation using NetLogo (Wilensky, 1999)

Series of built and un-built works by Mies van der Rohe are selected for the case studies. The spaces designed by Mies are relatively loosely defined in terms of the programs and the specific usages of each individual spatial compartment, thus results of human responses are less predictable, and they are considered to be suited for the study. The German Pavilion at the International Exposition in Barcelona (1928-1929) by Mies, usually referred to as the "Barcelona Pavilion" is one building on which the functionality of the Space Re-Actor will be tested. As a building type, a pavilion does not force any specific objective on the people visiting the building. Visitors' behaviors will be in direct response to the building's architectural features such as water features, benches, and sculptures, as well as to the transparency, opaqueness, or texture of the surface materials. They begin by wandering around the building and gradually find their ways toward what naturally attracts them. The visitors' behaviors are induced by the architectural elements present, and this condition is well suited for solely concentrating on evaluating the spatial conditions.

Synthetic figures are equipped with the following psychological responses to architectural elements, and the tool allows users to sketch and color-code the architectural elements to assign different qualities and characteristics to the materiality and features intrinsic to architectural spaces.

- Attractor-based Reaction: users can assign attractors such as sculptures or water features. They attract visitors' attention, and the visitors may halt for a moment to enjoy the views. For instance, the Barcelona Pavilion has two water ponds as major architectural features. Spatial allocation of these elements inside the overall composition by definition reflects the master designer's intention and motivation to shape people's circulation and experience. How the specific placement of those attraction features can manipulate the visitors' behaviors and contribute to the overall experience of the pavilion are the questions to be explored by seeing the real-time reactions of walking figures.

- Agents' Variable-dependent Reaction: Depending on a visitor's activity level, she or he might find comfort by sitting on the benches. Figures have an internal variable to measure their activity level (energy level) to check whether they feel like sitting or not. This type of attractor will be conditionally applied based on the internal variables of the figures. For instance, if the energy level is lower than a certain threshold value, they will start to seek the place to rest (furniture: Bench). After regaining the energy, they will go back to respond with the normal level of curiosity to other attractors.

- Visibility-based Reaction: "Can see and can be seen" is an important concept for the behavior of figures. The synthetic figures have vision, and some of their reactions are based on visibility. Better visibility allows them to find not only the attractors but also the others inside the space who could influence their next moves. The tool calculates the visibility at every coordinate point of the accessible space.

- Agents-to-Agents Reaction: Besides the simple avoidance and collision detections, interactions between the agents are considered. Having different degrees of sociability for figures, the tool can start to render an event in the scene. Heterogeneity among the agents governs the variations in interactions among the visitors. Some like to have more interactions with others and some do not. When two sociable people meet within a certain level of proximity on the street, conversation will start, and this begins to add a sense of place to the geometry.

Another implementation for the figures' behaviors is called Privacy mapping. Privacy mapping is a concept for gauging the level of privacy inside the space. This method is particularly interesting for analyzing residential spaces. I based the concept on two proposed criteria: level of exposure to the exterior environment (public) and the numbers of others who can see within the house. The first criterion can be simply calculated by projecting invisible rays 360 degrees around every point within spaces. Areas of visual exposure to the exterior in elevations are calculated using trigonometry, and it is simply the sum of these areas from the entire surroundings that indicates the privacy level of this coordinate point. This measure is based on agents' locations and is highly influenced by the materiality (transparency) of the walls and partitions inside spaces. Any change of the materials and their locations may affect this measure which provides spatial hierarchy based on the privacy.

One other criterion that I proposed is to measure privacy based on how many others are seen. When the density of the space is higher, people are likely to be seen by others, and this value will indicate the capacity of spaces that can maintain a level of privacy. The relationship between the distance around oneself and one's perception of others has been introduced the studies such as *Proxemics* by Edward T. Hall. In "*The Hidden Dimension,*" Hall suggests that four feet is considered to be "personal distance" which maintains a small hypothetical protective sphere between oneself and others. This dimension also varies, depending on one's cultural background, and is hardly ever objectified. It is an interesting idea to test the spaces with the different cultural dimensions possessed by various social groups. As a starting point of this study, any numbers of others within the dimension from Hall's studies, plus-or-minus four feet in radius as a threshold value, are counted as people who can greatly influence one's sense of privacy. Any others in visible areas outside of this distance are considered less influential; hence, those values decrease in inverse proportion to the distances from oneself.

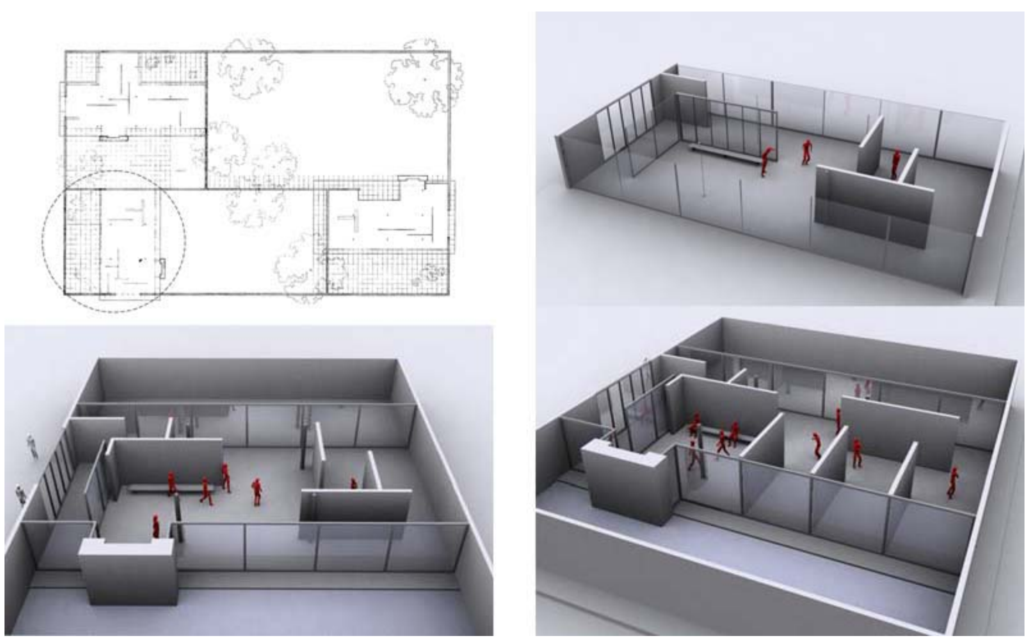

Figure 4. The group of court house by Mies (1931) and various Behavioral Responses from plan schemes with different degrees of Privacy using the Space Re-Actor

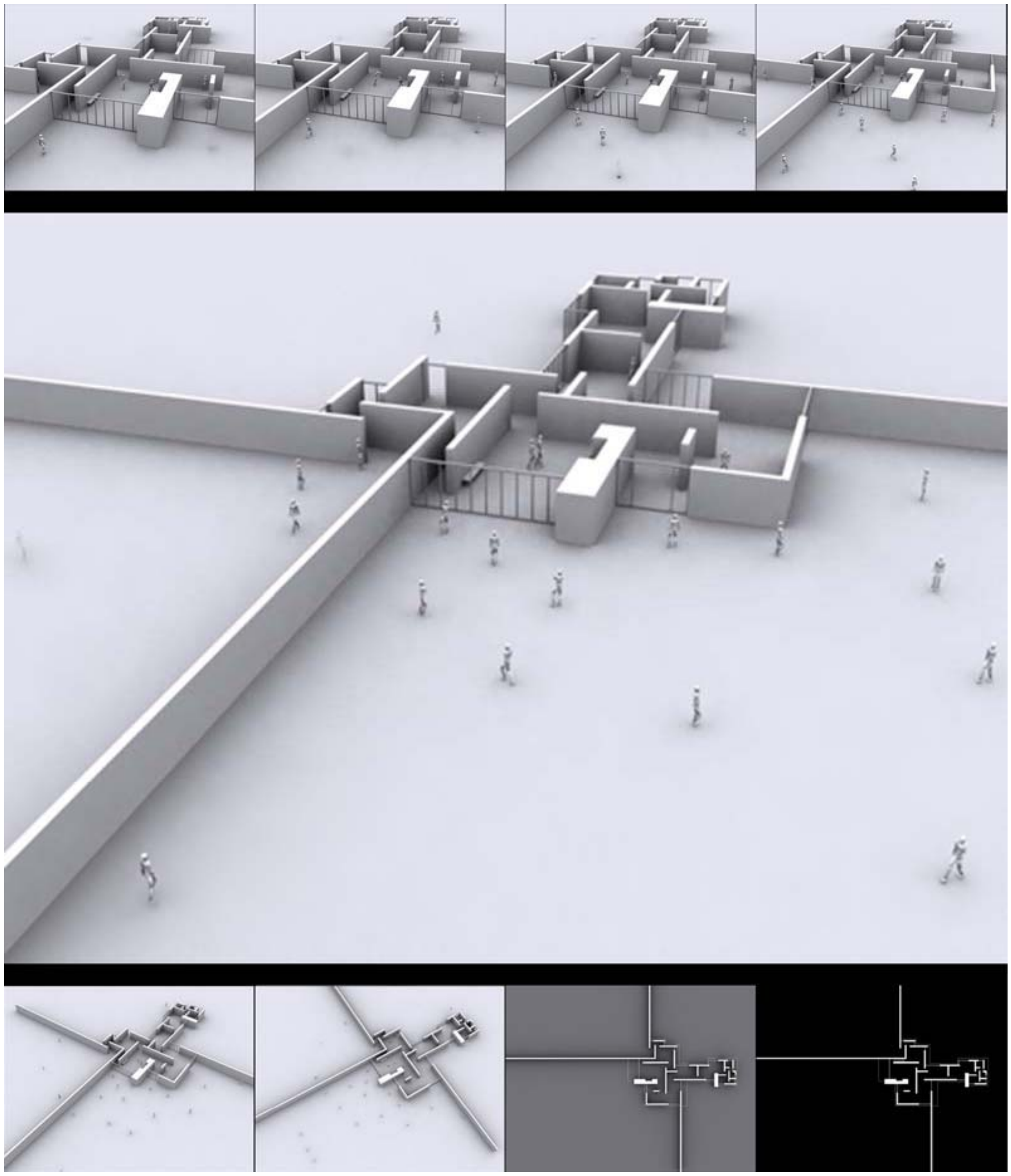

Figure 5. Brick Country House by Mies (1923) and Animated results from the Space Re-Actor

Every trial of the tool produces different possible events, based on the stochastic decision making process which is implemented in figures. A series of choices are chained and branched out from the current states of the figure. When figures have multiple choices, they will choose based on situations from their surrounding environments, their internal variables, and the different probabilities with which possible next states are weighted. Likelihoods of one behavior over the other can be expressed by directing randomness to a certain manner. Their chances of occurring are not uniformly distributed. For the sake of simulation, these differing probabilities are interpreted and applied to the figure's tendencies to select one state over the others. The interpretation of the events' likelihoods should ideally reflect patterns of human behavior in real-life. The aim of these exercises is to render the potential events and scenes of the building ideas, which had been left simply as states of geometry; to turn the results obtained into universally valid quantitative results is not the ambition of these experiments.

Discussion and Critique:

The animated result from the tool brings a sense of place to the geometry by displaying the figures in motion. By observing the scales and numbers of footsteps that it takes to move figures from one point to the other, viewers can obtain a sense of both speed and physical three-dimensional space. The tool's results offer a starting point for initiating users' conceptions of a space and help them to immediately study a spatial design as inhabited. Through considering the results that I have obtained from the series of experiments using the Space Re-Actor, I began to realize that the importance of the tool lies in the effort to integrate "human involvement" into a spatial design. A space seems to exhibit different characteristics according to the numbers of occupants, their objectives inside the space, and the proportions of groups with different degrees of sociability. Behavioral aspects of the spatial design have yet to be addressed well in any existing design tools. One may be able to obtain discrete numerical data about people's comfort levels as they depend on the density of a space through analytical means, but comfort and other characteristics in particular spatial layouts and conditions can be more fully grasped through the use of simulations. Aggregation of all the architectural components, such as doors, partitions, windows, staircases, and furniture in specific layouts can be understood through the use of "Enactment Software" such as the use of a synthetic figure in the Space Re-Actor.

Spatial qualities in architectural design cannot be fully evaluated solely by observing geometrical constructs without reference to inhabitants placed inside. The consequent emergent behaviors of people induced by characteristics of spaces may be impossible to predict, and indicate another layer of spatial qualities beyond the visible, formal, and aesthetic. A method for informing designers about the potential interactions between human behaviors and the spaces they are designing will constitute a valuable tool.

I understand that describing the people's behaviors computationally is a controversial issue here. That "an Agent-based model can never perfectly duplicate human social interaction" is a perennial critique and a genuine problem for the computer and social scientists involved in behavioral simulations. Simulations are always based on premise that human beings will behave in certain ways under specific conditions. Even though possible behaviors are incorporated from actual events and scenarios, there is no proof that the behaviors include all possible occurrences. The scope of reliability of results obtained through behavioral simulation is a critical bone of contention for researchers, not only in computer science, but also in operations research, social science, behavioral economics, and so on. However, I argue that the Space Re-Actor may more properly be considered as the first instance of a new category I am calling "enactment software."

Conclusions:

Generative grammars developed by leading scholars have successfully captured the design languages of many prominent architects. Implementation of psychological behavior and human intervention may add an interesting way to speak within this creative paradigm around "shape" and "grammar." The above-mentioned cultural dimensions may be derived from behavioral implementations. I would like to offer one observation concerning the comparison between existing geometry-based grammars and, so to speak, "behavioral grammar." The fact that many scientists involved with neural-coding are actively using probabilistic approaches such as Bayesian analysis suggests that any study involving our "self" requires some degree of understanding of indeterminacy. Unlike discrete and determinant geometrical operations, behavioral implementation can not be fully described without applying a notion of "indeterminacy." Describing a transition from one state to the other or one formal solution to the other by the decision of a human being may require a probabilistic treatment as is often true in nature.

Albert Einstein famously remarked that, "God does not play dice with the universe." However, facing apparent randomness in nature, one may sometimes doubt the accuracy of this view. The Space Re-Actor provides animated possible scenarios based on the qualities inherent in architectural spaces. The plausibility or persuasiveness of these results probably depends also on viewers' own attitudes and perceptions toward the "reality" around themselves. But the tool provides *multiple* interpretations of the spaces based on the stochastic decision process implemented in the figures, which is meant to reflect the indeterminacy of human behavior.

"Reality," I believe does possesses indeterminacy. Who knows what types of people are visiting at particular times of the day in Mies's country house? Every trial of the tool produces different possible events, and the original intention was to identify tendencies in behaviors and actions by seeing series of possible scenarios. What we have witnessed in the several visualization results of the Space Re-Actor may not be certain to occur in reality. However, neither can one completely deny the potential occurrence of such events. One's attitude toward "reality" will surely influence how we regard this new tool, the Space Re-Actor.

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