

Automatic Walkthrough Utilizing Building Information Modeling to Facilitate Architectural Visualization

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Abstract. *This paper presents a new system that supports automatic path planning for walkthrough in building models, using information retrieved from Building Information Modeling (BIM). It can automatically generate a path that explores all or part of the rooms in a building. During a real-time walkthrough, users will be able to follow the path while interactively controlling their viewing angles. That way, users can take guided tours while simultaneously looking around to examine the spaces. We expect the system to be useful in design review because BIM models of design can be easily brought into the system that allows reviewers to start walkthrough immediately and interactively. The significance of the work is that the system has potential applications for visualization of complex building design.*

Keywords: *Walkthrough, Building Information Modeling, Visualization.*

Introduction

The problems of current path planning for interactive walkthrough and pre-rendered animation for architectural visualization include the following: (1) Users easily get lost because of complex environments and lack of cues due to the difficulty in path planning. (2) Excessive freedom of movement increases the difficulty of taking natural paths as in the real world; for example, users often bump into walls or take unnaturally sharp turns. (3) Raster-based maps used in path planning have no knowledge about environmental elements such as buildings, lawns, fountains, etc. This causes inappropriate paths allowing users to draw their paths in areas that are inappropriate

for walking, such as the roofs of buildings on a map. (4) Designers or users of virtual spaces often prefer specific paths for others to visit in order to present their design or interests, but they have no control of where users will go, unless the paths can be stored and retrieved in real-time. (5) Manually planning a representative and smooth path in a building model remains a difficult task as found in our design visualization course for environmental design students.

Previous research has addressed some of these issues separately by adding global maps in addition to local views (Elvins, et al, 1998; Fukatsu, et al., 1998), adding various landmarks (Darken, et al., 1996; Vinson, 1999; Cliburn et al., 2007) to help path finding, and using the “river analogy” (Galyean, 1995)

or “StyleCam” (Burtnyk, et al., 2002) to guide and enable users to deviate from preconfigured paths; however, each of these methods alone cannot provide a satisfactory solution. Adding maps or landmarks cannot solve the natural path and the guided tour problems; the “river analogy” or “StyleCam” does not provide map knowledge, leaving users with a lack of context for path finding and capability for path planning. These approaches also do not address the problems of inappropriate paths, and real-time path saving and retrieving.

A more comprehensive navigation system implementation (Yan, 2006) includes the following features: (1) It integrates an interactive perspective view and a smart map. (2) Path control information merges into users’ interactive walkthrough. (3) Paths with related information save in real-time over a network and have the ability to load and replay at a later time.

Despite being a more comprehensive solution, the above system was still built based on manual path planning. Our new solution builds upon previous work through the addition of automatic path planning, as the emergence of Building Information Modeling (BIM) techniques into the design community provides a great opportunity for design simulation and visualization to utilize the information that can be retrieved from BIM models.

The significance of the new work described in this paper lies in that the system has potential applications for visualization of complex building design, such as airports or shopping centers, to automatically generate paths for interactive walkthrough and pre-rendered animation. Furthermore, it may be used for human behavior simulation in built environments.

Methods and Implementation

We created an automatic path planning system using BIM models, such as the sample shown in Figure 1. Our system possesses knowledge about room connectivity relationships in the models that may be visualized in the form of undirected graphs (Figure

2). It can automatically generate a path from a start room to an end room as well as generate “complete” paths that explore all rooms in a building or a part of the building depending on the purpose of the walkthrough. Users can select the start room and the end room, or a series of rooms to walkthrough (Figure 3). During a real-time walkthrough, users will be able to follow the paths while interactively controlling their viewing angles. A camera can be mounted on the head of a virtual user walking along generated paths. Figure 4 shows such a path, and Figure 5 screen captures show user adjustable viewpoints while following an automatically generated path calculated based on user input of selected rooms.

Implementation of the automatic path planning system is demonstrated by a prototypical system utilizing Autodesk Revit – a BIM modeler and its Application Programming Interface (API), which allows access to all building elements including rooms and doors, and their geometrical and non-geometrical properties. The result of the walkthrough system is simulated and visualized using Microsoft XNA Game Studio Express. The walkthrough system is created based on our re-written and much improved version of the BIM-Game system (Yan and Liu, 2007).

The automatic path planning approach begins with the extraction of door and room element properties from the Revit document database. This involves using the Revit C# .NET class libraries to cast document elements into door and rooms, and determine whether or not the elements contain special parameters. The door family type has an augmented configuration that contains two special shared project parameters that specify the relationship or connection between adjacent rooms: Room1 and Room2. The path planning software immediately recognizes the built-in properties of standard Revit rooms for use in connection development. The implementation uses these parameters to construct an undirected graph that represents room connectivity in the BIM model (Figure 2). This graph forms the basis from which an automatic path originates.

The next step in the path planning process

Figure 1
 Floor plan of an apartment building made with Autodesk Revit Architecture 2008. Rooms are color coded. Each door or opening has the parameters of which two rooms it is connecting. (Model source: sample of Autodesk Revit Architecture 2008)



determines which paths to construct along the graph edges based on a starting and ending room or location. Three-dimensional Cartesian coordinates attached to the elements provide sufficient data to compute distances between one element to another. Nodes on the graph represent rooms while the edges of the directed graph constitute weighted values corresponding to the distance between those rooms or nodes for which the door connects. In the cases of doors and rooms, the procedure computes a pseudo-centroid of the respective geometry by examining the bounding boxes that contain the element. Path planning uses the connectivity and distance values to employ shortest path searches using Dijkstra's algorithm to determine the most efficient routes from one room to another. The solution of this algorithm feeds into a path constructor that inserts a series of three-dimensional XYZ axis-aligned coordinates into a dynamic array of control points. The final path derives from a cubic

B-spline basis interpolation of these points, resulting in a sufficiently smooth traversal of the path in space (Figure 4).

This path, in conjunction with geometrical data from the Revit BIM model, supports a framework of objects that integrates into the XNA platform for animated, interactive BIM review. Users may choose to analyze their models through real-time interactive walkthroughs with unrestricted movement along preconfigured paths or to follow these paths while having control over the look direction, including tilt and panning. Both of these approaches makes use of standard game keyboard commands such as the keys A, S, D, W, and arrow keys, and a Universal Serial Bus (USB) capable Microsoft Xbox 360 console controller for more natural navigation. This bridge between real-time game play and BIM enhances the design process and assists in problem solving while immersing users in an interactive environment that has intuitive navigation controls.

Conclusions and Future Work

In this paper we presented a new BIM-based architectural walkthrough system. The system can be used to automatically generate paths, and it allows users to follow the paths while controlling their viewing directions interactively. That way, users can take guided tours while simultaneously looking around to examine the spaces. We expect the system to be useful in design review because BIM models of design can be easily brought into the system that allows reviewers to start walkthrough immediately and interactively.

Our future work includes the implementation of the following features: users can make changes to the paths before starting a walkthrough or rendering one for animation; during a real-time walkthrough, users will be able to follow the paths while interactively deviating from the paths; more realistic views embedding the head movement can be simulated for the walkthrough; the system will be integrated with previous work addressing other aspects of

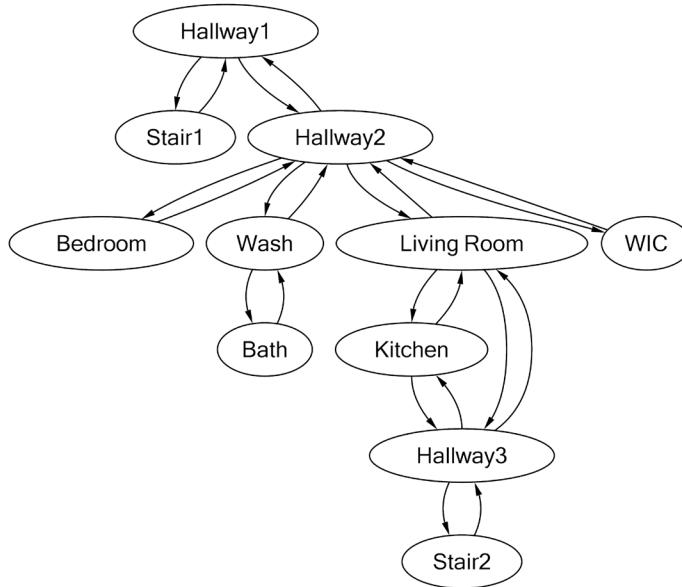


Figure 2
Room connectivity graph, with rooms as nodes, and door and openings as edges, is generated automatically based on the BIM model by our program using Microsoft GLEE - a graph layout engine. The graph enables path finding algorithms to be used for automatic path planning.



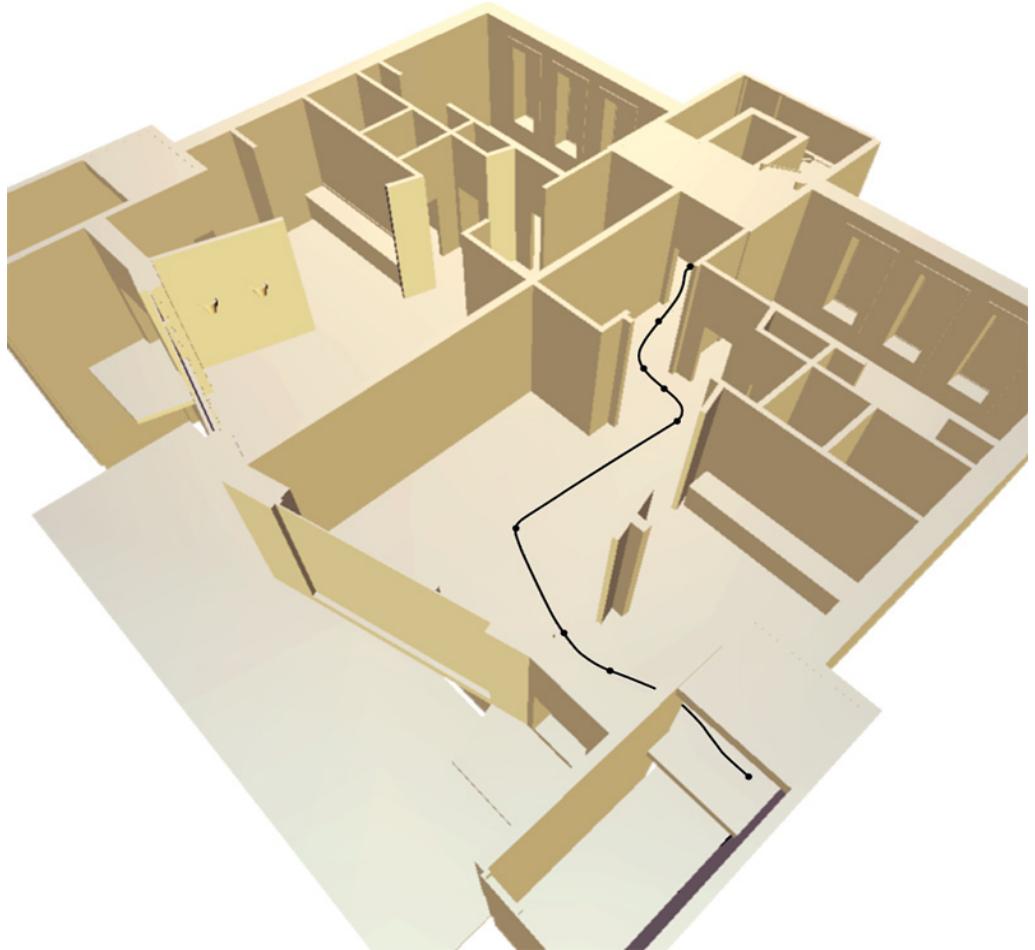
navigation mentioned in Introduction; and finally, evaluation of the system in design visualization courses using students projects.

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Figure 3
User interface for selecting rooms to walkthrough. Show Graph and Follow Path functions were used for the case study in the paper, while Walk Through function can be used for free walkthrough given a starting location.

Figure 4
Visualization of path planning showing the BIM model in shaded mode with a path finding representation as a smooth, black curve. Path control points or dots exist at the center of rooms and at doors. This path begins at Stair1, continues through the Living Room, and ends at Stair2.



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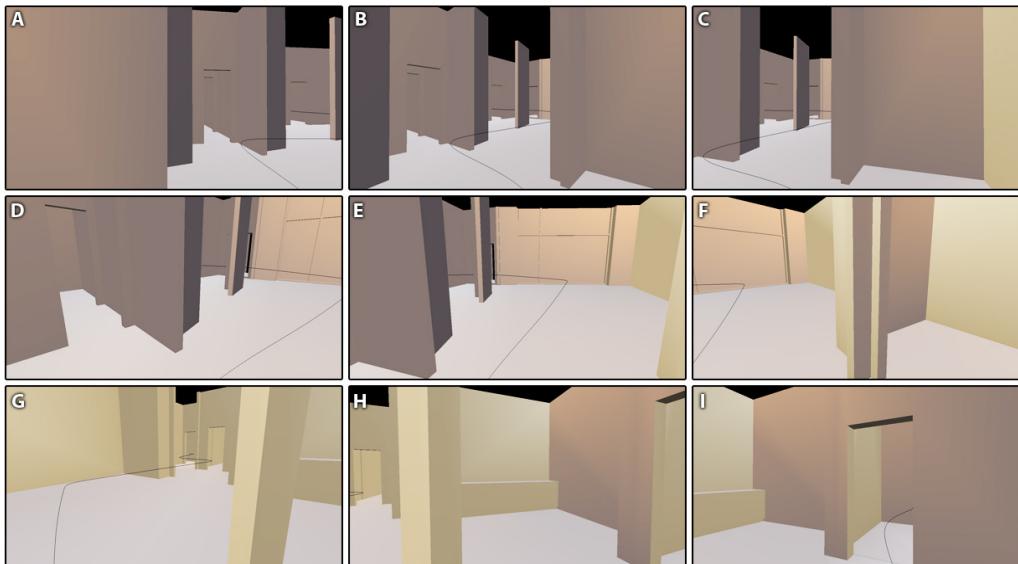


Figure 5
 Nine screen captures showing user adjustable viewpoints while following an automatically generated path calculated based on user input of selected rooms. A, B, and C demonstrate viewpoint deviations to the left, center, and right, looking in the forward direction. D, E, and F show similar deviations at a location farther down the path. G, H, and I show a location near the end of the path, looking in the backward direction (G) and revolving around (H) to look in the forward direction (I). The thin lines in the screenshots show the generated path that the camera was following.