

# The Interactive 3D BreakAway Map: A navigation and examination aid for multi-floor 3D worlds

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## Abstract

*In this paper, we propose the Interactive 3D BreakAway Map (I3BAM), an extension of the well-known Worlds In Miniature [6]. The I3BAM supports user navigation in virtual buildings as a navigation aid, but also provides a means of examining any floor of a virtual building without having to necessarily navigate it. The aid presents multiple views of a virtual building and provides information about both the internal and external structure of a building. The paper also includes some implementation details and shows an application of the I3BAM to help users learn how to navigate real buildings.*

## 1. Introduction

Navigation is an important aspect of interaction with a Virtual Environment (VE). Users of VEs need to understand the space that surrounds them and find their way around. Unfortunately, the process of navigation – whereby people determine where they are, where everything else is and how to get to particular objects or places – is often difficult: people get lost and their searches frustrated [10].

Navigation problems become even more serious in large scale VEs. There is no vantage point from which the entire world can be seen in detail, and the amount of detail that can be seen (e.g., from a bird's eye view) is drastically reduced due to occlusion, as it happens in virtual buildings containing multiple floors.

In several VE applications, users navigate 3D buildings. Typical examples can be virtual shopping malls; virtual museums; 3D games; virtual reality based training simulations where users learn routes and building structure so that the knowledge gained may

be applied in real life scenarios [1]; virtual models of complex real buildings where structural changes necessary to rectify design defects is not feasible, thus creating the need for alternative solutions [2].

The goal of navigation aids research is to create solutions to help the user explore and learn the environment around her and prevent her from getting lost, simplifying navigation, which often is only an intermediate task that the user needs to perform inside a VE together with other tasks (e.g., object manipulation, collecting information etc.).

In this paper, we propose the Interactive 3D BreakAway Map (I3BAM), an extension of the well-known Worlds In Miniature [6]. The I3BAM supports user navigation in virtual buildings as a navigation aid, but also provides a means of examining any floor of a virtual building without having to necessarily navigate it. The aid presents multiple views of a virtual building and provides information about both the internal and external structure of a building.

The paper is organized as follows: section 2 summarizes some major approaches to navigation support in VEs, section 3 motivates our proposed aid, section 4 illustrates the proposed aid in detail, section 5 provides a brief description of its implementation, section 6 describes an application where the aid is being used to learn navigating real buildings. Finally, section 7 presents the conclusions and future work.

## 2. Related Work

To navigate effectively an environment, users resort to two distinct types of navigational knowledge. *Route knowledge* is usually developed from a first person perspective (egocentric) and describes paths between locations in the environment. It allows a user to travel to destinations through known routes, but does not

allow the user to take alternate unfamiliar routes. *Survey knowledge* is developed from a third person perspective (exocentric), describes relationships among locations, provides the mental equivalent of a map and allows one to recognize alternate routes between locations [9].

Navigation support in VEs can be provided in two different ways: building VEs that follow navigability guidelines and providing navigation aids to help the user. Approaches based on the first category include using an organizational structure to divide an environment [15], providing navigational cues (landmarks, signboards etc.) within the VE, increasing visual access (how much of a VE can be seen from a position in space), .... The second category focuses instead on providing new functionalities (*navigation aids*) that actively help in the task of navigation. The earliest navigation aids were electronic analogues of aids used by people in the real world (virtual compass, miniature maps, virtual sun etc.). Electronic miniature maps provide a convenient way to present users with an overall view of the environment they are navigating. To make efficient use of the information presented by miniature maps, users need to be able to relate the scene as they see it (first person perspective) to what it is on the map (third person perspective), a process that requires considerable cognitive effort and which has been shown to be difficult [16,17]. Electronic maps can however have additional features that are not available in paper maps (self-orientation, interactive position and orientation indication, etc.). However, as far as large-scale VEs are concerned, a single map cannot simultaneously provide the level of detail needed for local navigation and a global view of the entire environment. For this reason, Ruddle et al. [4] propose the simultaneous use of a global and a local map.

Many of the miniature map-based navigation aids are based on 2D maps. The WIM (Worlds In Miniature) aid proposed by Stoakley [6] employs instead a 3D representation. A WIM is a 3D miniature version of the VE, floating in front of the user, as if it were in her virtual hand. The user's position and orientation are indicated in the WIM. It also provides the user with object manipulation and navigation capabilities [6]. As pointed out in [13], WIMs appear best suited within bounded environments, such as virtual rooms with walls and floors. Thus, the WIM can be employed in virtual buildings, which are one of the most common types of VEs. The next section will discuss the WIM in further detail.

Miniature maps can support map-based travel techniques. User's position is represented by an icon on the 2D map. To travel, the user drags the icon to a new

position on the map. Once the user drops the icon, the system animates the user's transition from the current location to the new location. Another technique is that of "teleporting". Once the user indicates the target position on the map, she instantaneously jumps to the target location. However, automated point-to-point navigation can limit the spatial knowledge users gain from the experience. Users may be shown (and thus may learn) little or nothing about the route (and its surroundings) between initial and target locations [19].

Virtual buildings differ in structure from other VEs such as open ocean environments or landscapes of data and need appropriate navigation techniques suited to them. For example, the 3D arrows navigation aid proposed in [12] works well in VEs representing large-scale urban environments (for instance) but would be ill suited for virtual buildings.

### **3. Extending the WIM for Virtual Buildings: Motivations**

A navigation aid for virtual buildings should provide the user with: i) a view of the external and internal structure of a building simultaneously; ii) structural details of every floor; iii) a view of her immediate surroundings in the global context of the building; iv) a mechanism to avoid or at least reduce the occlusion caused by the presence of multiple floors; v) support in exploring the virtual building which would allow the user to build up survey knowledge; vi) support for route following in the virtual building which would allow the user to build up route knowledge; vi) easy interaction.

As described previously, the WIM is a well-known metaphor that uses 3D miniature maps to represent the user's immediate surroundings. The user navigates the environment from a first-person view and the WIM provides her with a third-person view.

However, the WIM has shortcomings that do not make it directly applicable to virtual buildings, hence requiring an extension. First, merely presenting a WIM of an entire building would not provide a means of studying both the external and internal structure of the building (floor wise), the importance of which has been stressed by recent work in building structure visualization [5] which points out that most 3D model viewing applications lack the ability to simultaneously display the interior and external structure of the environment. There are interfaces that allow the user to either view the external structure (e.g., "ArcBall" interface) or the internal structure (walkthroughs) at any point of time, but do not allow the user to understand the environment as a whole, because the

walls and floors create occlusions and obstruct a clear view of most of the structure. The solution proposed in [5] is an interactive system that provides automated support for producing exploded views of architectural environments, processing and analyzing low-level geometry to detect and separate building geometry on a floor by floor basis. The concept and the technical implementation of the solution are described in [5], but there is no mention of how the proposed solution could be integrated into the navigational experience of a user.

Second, the WIM has been implemented for single rooms or single floors (e.g., [3]) but the problem of visualizing more than one floor of a building while trying to avoid/reduce occlusion is left unsolved in these implementations.

Third, in the originally proposed WIM-based navigation the user moves an iconic representation of herself or manipulates her viewpoint in the WIM, and the system then flies her to the new position or updates her viewpoint in the full-scale VE. These actions are confusing, because the user's focus of attention is in the miniature, not in the full-scale virtual world [7]. Considering navigation in a building, when a user wants to go from her current position to another one, she generally follows some path through the stairs and corridors. Following this path (as opposed to instantaneous jumping) is important to give the user knowledge of the relative location of objects in the virtual space [14]. Thus, providing navigation assistance through "pick and place yourself" techniques is not the best choice, if users are to gain knowledge about routes and internal structure of the building.

Fourth, the WIM may be unsuitable for representing large spaces, since it would be too detailed for users to comprehend. A lower level view, that shows part of the large VE, would provide some scrolling or selection techniques, yet still lack the ability to view the entire context [11].

A previous attempt has been made at applying the WIM to virtual buildings: a dataglove-based technique called "The Saw" [8]. This WIM implementation allows one to access occluded detail, an unavoidable aspect of complex enclosed interior spaces. The Saw is a planar virtual cutter operated by one of the user's hands, while the other holds the WIM. A motion tracker attached to a data glove allows the user's hand orientation itself to represent the plane of the Saw. When the Saw is brought into contact with the WIM, all the detail on the "cut" side is removed. A toggle switch allows the user to toggle between full and cutaway views of the WIM, to maximize the ability to place local spatial information into a global context. The ability to place local spatial information into a

global context is one of the extensions to the WIM that the I3BAM provides, but in a simpler way and without needing a dataglove.

## **4. The Interactive 3D BreakAway Map (I3BAM)**

The I3BAM extends the WIM and applies it to virtual buildings with the aim of providing: i) easy to understand information to help the user gain both route and survey knowledge of a building; ii) easy interaction; iii) the capability to study the structure of any floor without having to navigate it; iv) multiple views of the building, including a view of user's immediate surroundings with respect to the global context of the building; v) support for exploration and route following.

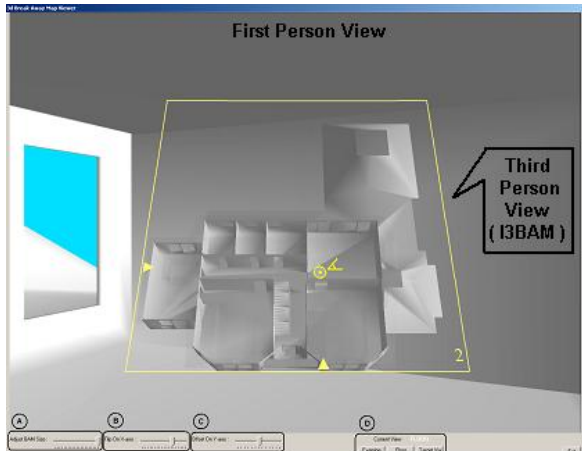
The I3BAM does not provide "pick and place yourself" travel functions for the reasons mentioned in the previous section. Instead, the I3BAM acts as a navigation aid while the user travels the VE using the common walking metaphor. Moreover, it provides the user not only with knowledge about the external and overall structure of a building (e.g., the number of floors, exits,...) but also the internal structure of the building (e.g., how the floors are connected by staircases, where staircases are located, structural details of each floor,...).

### **4.1. The I3BAM and its controls**

The I3BAM is a miniature 3D model of the building the user is navigating, constantly floating in front of the user (Fig 1). Alternatively, the user can choose to display it in a secondary tiled window (at the expense of some screen space). The I3BAM provides the user with 3 different views ("Examine", "Floor" and "Target", described in the following subsections). Any change to the I3BAM (due to any of the 3 views being activated) does not affect the actual virtual building.

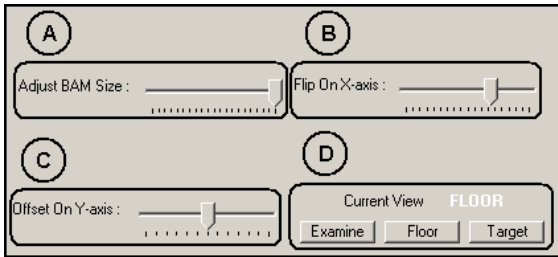
The I3BAM can highlight a specific floor by displaying a rectangular outline (floating) just above it, with the corresponding floor number being displayed at the lower right corner of the rectangular outline, (e.g. Fig 1 shows how floor 2 is highlighted). The I3BAM can visually indicate the position (and orientation) of the user or a target on a floor, by displaying a colored glyph (of the same color as the rectangular outline) at that object position. Moreover, two arrowheads along the sides of the rectangular outline indicate object position along the length and breadth of that floor. User's position and orientation are indicated by means of a glyph (a sphere with an inverted triangle in front of

it, see Fig 1). A target's position is indicated by means of a darker colored glyph (only a sphere). User's position, orientation and the arrowheads are updated in real-time as the user moves.



**Figure 1: The I3BAM with the related controls**

Three operations - scale, position and flip - are always available to the user by means of appropriate slider controls. Fig 2 provides a magnified view of the control panel shown at the bottom of the screen in Fig 1.

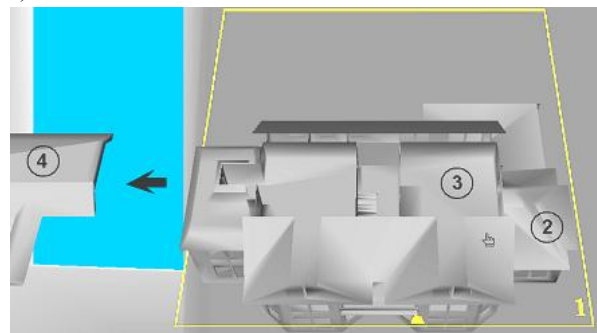


**Figure 2 : The I3BAM controls**

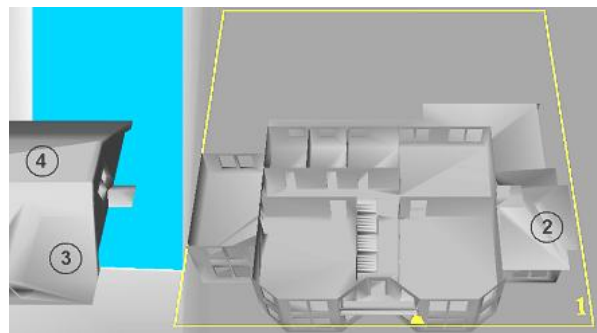
In Fig 2, the slider labelled as A) is the scale control used to change the size of the I3BAM. By default, the I3BAM appears with the size shown in Fig 1, which can be reduced if needed. The slider labelled as B) is the control used to change the flip angle of the I3BAM. The range is between 0 to 90 degrees along the horizontal axis. In other words, the flip angle can be changed to obtain anything ranging from a front view to a top down view of the building. The default is 45 degrees. The slider labelled as C) is the position change control used to change the position of the I3BAM along the vertical axis. On the horizontal axis, the I3BAM is always at the center of the screen. The group of buttons labeled as D) allows one to change among the different views provided by the I3BAM. The currently active view is indicated in white colored text in the control panel. The transition between any pair of views is animated to prevent disorientation.

## 4.2. Examine View

In Examine view, all the floors of the building are visualized. This will inevitably cause occlusions. We thus provided the I3BAM with a floor sliding mechanism. Each floor of the I3BAM slides horizontally outward or inward (with respect to the rest of the building structure) when clicked in this view. This allows the user to move away floors that obstruct the view to a particular floor and study the structure of that floor. Displaying the structure of any single floor could also have been achieved by making all other floors disappear. However, we chose to use the floor sliding mechanism in this view, since it can make users more aware of how the floors are organized to form the complete structure of the building. The floor-sliding action is toggle-controlled. One click slides a floor outward from its initial position, another click slides it back to the initial position. For example, being on floor 1 (highlighted by the white rectangle in Fig 3 and Fig 4), the user is able to examine the structure of floors 2 and 3 without navigating them. In Fig 3, the user clicks on floor 4, which slides out in the direction of the arrow, revealing the structure of floor 3. The user then clicks on floor 3 to reveal the structure of floor 2 (Fig 4).



**Figure 3: Examine view (before click on floor 3)**



**Figure 4: Examine view (after click on floor 3)**

### 4.3. Floor View

In Floor view, the I3BAM displays mainly the floor on which the user is walking and the rest of the building becomes semi-transparent. This makes it possible to use the view as a 3D map to navigate the current floor. For example, the I3BAM in Fig 5 shows only floor 1 (highlighted by the white rectangle) which is the user's current floor. The rest of the building is rendered 90% transparent. User's position and orientation are shown and her position is also displayed along the length and breadth of the floor by means of the arrowheads.

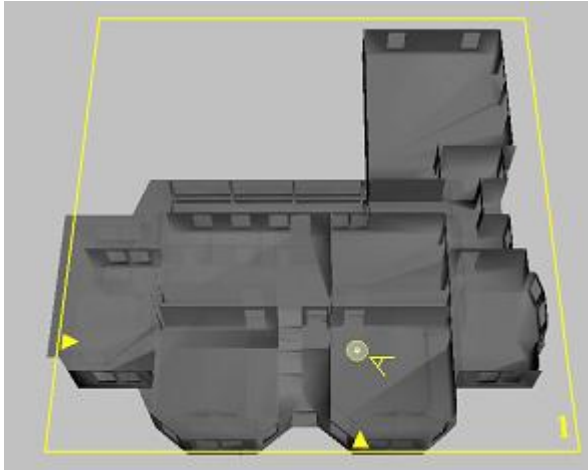


Figure 5: Floor view

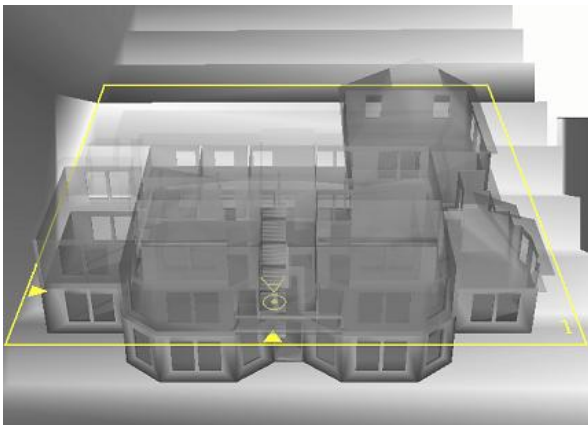


Figure 6: The user walks on a staircase

When the user is walking on staircases, the Floor view presents an animated display of the two floors between which the user is “transitioning” using varied transparencies as follows. As long as the user is on the staircase, the higher floor is semi-transparent. The lower floor is completely opaque. The flip angle is varied from 0 degrees (front view) when the user is at one end (top/bottom) of the staircase, to 45 degrees

when she is at the middle of the staircase, back to 0 degrees when she is at the other end (bottom/top) of the staircase. Hence, when the user walks on a staircase the flip angle of the I3BAM is changed and the floor transparencies are changed (as explained previously) to provide the user with a convenient view. For example, in Fig 6 the user walks on a staircase leading to floor 2 from floor 1. The higher floor (floor 2) becomes semi-transparent and the lower floor (floor 1) becomes completely opaque.

### 4.4. Target View

In Target view, the I3BAM simultaneously displays the position of the user and a selected target within the global context of the entire building, enabling the user to assess her own position with respect to the target and decide how to reach it. The transparencies of the floors on which the user and target are respectively located and all other floors are varied as follows to provide the best possible view to the user. Let us call ‘Higher’ the higher among the user and target floors and ‘Lower’ the lower one. All floors below the Lower floor are completely opaque. All floors between the Lower and Higher floor are 90% transparent. The Higher floor is 50% transparent. All floors above the Higher floor are completely transparent.

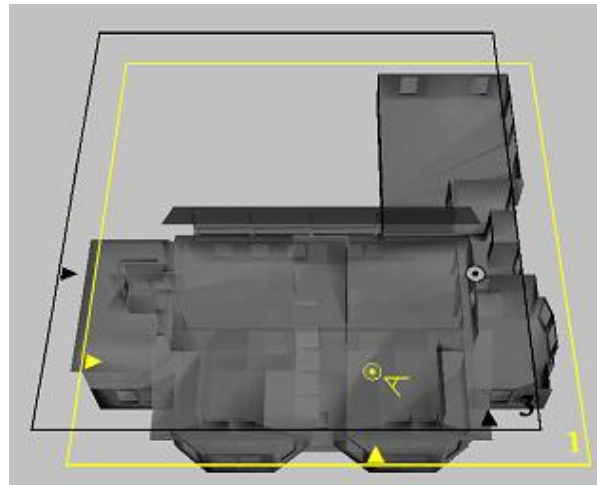


Figure 7: Target view

For example, in Fig 7 the I3BAM shows user's position and orientation on floor 1. The target position is indicated with the black colored glyph on floor 3. The two black arrowheads along the length and breadth of the target floor outline are also displayed. The arrow pairs (white and black) are provided to help the user reach the target position precisely (once on the target floor, the user moves towards the target until both the white and black arrow pairs coincide).

Exploiting transparency to simultaneously display the position of the user and the target was a decision based on user tests we made with semi-transparency [18], which indicated that users could make use of semi-transparency to improve wayfinding performance.

#### 4.5. Using the I3BAM in navigation

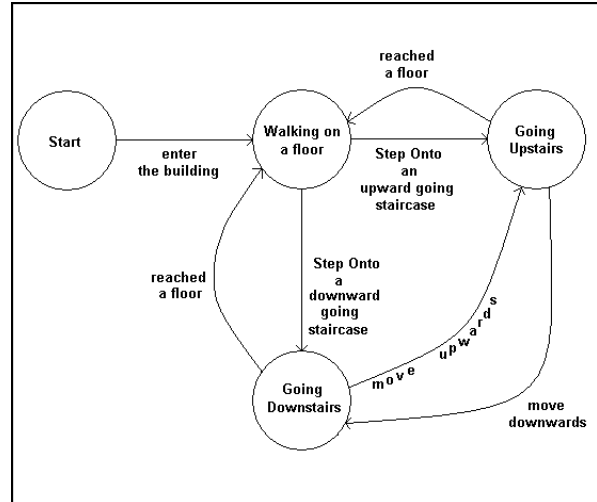
The three views are visually very different and easily distinguished. Regardless of the currently active view, the user is always made aware of her position and orientation. When the user wants to find a route to a particular target, she can switch the I3BAM to the target view to find out the relative position of a target. Then, during movement, she may prefer to use the floor view (more often) than the other two views due to its visual simplicity. The examine view can be used when the user needs to study the structure of a particular floor, without necessarily having to move at the same time.

The user can gain route knowledge by active navigation in the building and making use of the I3BAM during navigation. The I3BAM makes the user always aware of her own bearings with respect to the relative position of a target as she takes a route to it. Furthermore, survey knowledge can be gained by using the examine mode possibly coupled with active exploration of the building.

### 5. Implementation

To support the I3BAM, we built an application called the I3BAM Viewer implemented in Visual Basic and VRML. Visual Basic has been used to build the graphical interface of the I3BAM Viewer, higher level event handling and controlling dynamic 3D content. All 3D content is created in VRML. The Cortona VRML browser [20] integrated into the I3BAM Viewer displays the 3D content. All interactions between the Visual Basic code and the VRML world are handled through the API provided by the VRML browser. The I3BAM Viewer uses the state diagram shown in Fig 8 to follow user's behaviour and identify the user's navigation state within a virtual building.

The I3BAM Viewer monitors different types of events whose occurrence might result in changes to the I3BAM. The main type of event is a state change in the diagram of Fig 8. Other types of events include mouse clicks on one of the view selection buttons to change the currently active view, using the controls in the control panel, mouse clicks on floor geometry in the Examine view, a change in the position/orientation of the user,...



**Figure 8: User navigation within a building - state diagram**

The I3BAM can be automatically generated for any 3D virtual building provided its structure is consistent with the following representation assumptions. To get a generic building structure representation, we assume that all the geometry belonging to a floor is grouped under one parent node in the scene graph hierarchy. Then, the entire building itself is represented as a top-level root node for which the floor nodes are children. Additionally, the floor geometry must be represented using a parametrized geometric object definition (called PROTO in VRML), that includes a simple transparency parameter, used to change the transparency of that floor geometry in the Floor and Target views. Since each floor geometry is contained in its own parent node, it is possible to detect mouse clicks on that parent node (hence the floor geometry contained within it) via the VRML browser. Thus, when the user clicks on the geometry of any floor, a geometric translation is applied to move the entire floor outward or inward (in the Examine view). The distance by which a floor moves is the width (along the x-axis) of the bounding box of the entire building.

Thus, given the VRML source code of any building model (consistent with the previously mentioned assumptions), it is possible to view/navigate it using the I3BAM Viewer.

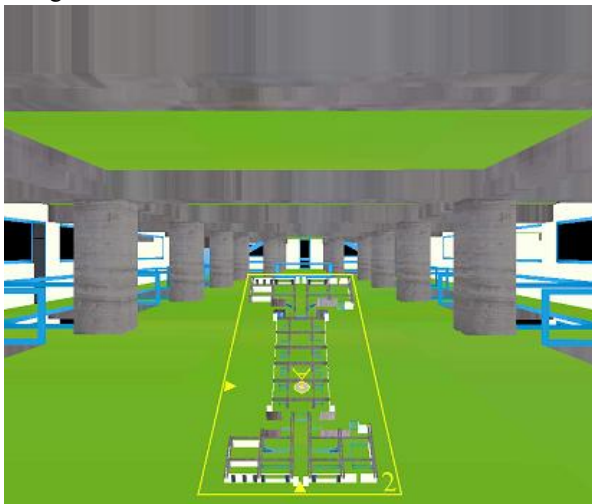
### 6. Using the I3BAM to learn how to navigate real buildings

Besides being useful for virtual worlds, the I3BAM also helps users to learn building structure and routes within virtual reconstructions of real buildings. First, users learn routes to target locations by navigating

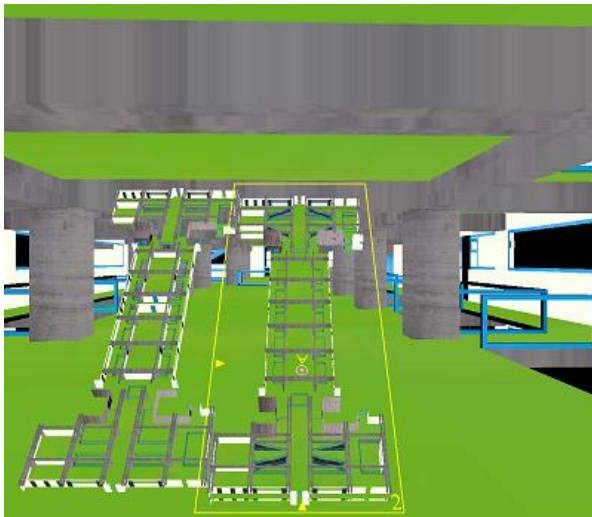


inside a virtual reconstruction of a real building using the I3BAM. Then, the routes that have been learnt can be followed in the real building.

We have applied this idea to our three-floor university building (Fig 9 and Fig 10) which is large and has a complex structure. Many first-time visitors are indeed confused when looking for an office in the building. A menu of offices and the names of the people that work in them has been added to the main interface of the I3BAM Viewer. The user can select a person's name from the list. The I3BAM then shows the position of the target location (the person's office) using the Target view described in section 4. The user can then switch the I3BAM to the Floor view while she navigates.



**Figure 9: Navigating the 3D university building using the Floor view.**



**Figure 10: The I3BAM Viewer in Examine view.**

## 7. Conclusions and Future Work

The I3BAM extends the WIM to overcome some of its shortcomings, applying it to virtual buildings as a navigation aid and as a tool that enables study of any floor without necessarily having to navigate it. We are now evaluating it on users and preliminary results are promising. We plan to carry out a training transfer study on the application that concerns our university building. This study will investigate how effectively a user who has learnt a route to a particular target position while using the I3BAM is able to transfer that knowledge to the real building. We are also currently working on the development of tools to apply the I3BAM to previously created building models and on the integration of a path planning algorithm to provide detailed route indication capabilities.

The I3BAM has been tested successfully for building models having up to 5 floors. Application to taller buildings such as skyscrapers encounters scalability problems. We plan to face this problem by studying adaptive techniques for controlling the level of detail in the I3BAM and to increase interactivity in very large buildings.

## 8. Acknowledgements

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