New Perspectives on Built Environment Models for Pedestrian Navigation

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Abstract. We present a map modelling toolkit that meets the special requirements of pedestrian navigation in intelligent environments. Its central component is a graphical editor, which supports the geometric modelling and visualization of built environments in 3D. Multiple levels and their interconnections, such as ramps and staircases, can be represented through layers. The toolkit also integrates a route finding module for pedestrian navigation applications. The model and the route can be shown as an orthogonal (map-like) projection or from different perspective viewpoints; the allocentric viewpoint shows the model from outside (bird's view), the egocentric viewpoint shows the model from the user's perspective inside the building. Landmark objects can be included and the visibility of signage or public displays can be virtually evaluated using the avatar. Various animations can be created to visualize the route, including transitions between the perspectives.

Keywords: location modelling, pedestrian navigation, intelligent environments

Motivation

Our research aims towards systems that provide ubiquitous navigational aid for pedestrians, with an emphasis on indoor environments. The situation of a pedestrian differs from driving tasks, since the user is not bound to follow paths or streets. Instead users typically cross open spaces, directly following their line of sight. The model has to particularly reflect this and represent places as polygonal objects, in contrast to ordinary street map databases, which usually consist only of line segments in two dimensions. The big providers of navigational maps for mobile systems have recognized the benefit of three-dimensional visualizations, but they are still focused on outdoor environments. As pedestrians spend most of their time inside buildings, indoor environments need to be modelled in 3D with multiple floors and landmarks. Inside, decision points are more complex than outdoors because stairs and elevators add choices. For the same reason, routes can not be depicted easily in a single map, so that indoor wayfinding tasks generally pose a high cognitive load to the user.

Assisting the user with mobile devices however is quite challenging, because no standardized positioning technique like GPS is available for buildings, and electromagnetically noise often hinders the estimation of the user's orientation by a compass. Hence we focus our work on digital media signage because the location of the displays is exactly known to the system. Some of our research questions are: where to place displays, how many do we need, and how to present route instructions.

The Yamamoto Toolkit

Our toolkit, which is called *YAMAMOTO* (**Y**et **A**nother **Ma**p **Mo**delling **To**olkit), see also [2], is positioned between proprietary two-dimensional location models that are typical for ubiquitous and pervasive computing research projects on indoor navigation, and professional three-dimensional CAD (Computer Aided Design) tools for architects. CAD tools require a high level of experience; the designer has to manually cut out windows and doors from solid walls and has to take care about window sills, choices of door handles or steps of a staircase. Such a high level of detail is not required for route finding and presentation purposes. Our approach strives to minimize the modeling effort. By following the motto to keep everything as simple as possible, we have intentionally reduced the degrees of freedom by half of a dimension in order to allow for a simpler and easier to learn user interface.

As the toolkit has been designed with pedestrian navigation in mind, it also includes a route finding module. It is able to generate routes between any two points in a model, which follow the line-of-sight whenever possible and does not require a predefined and restrictive path network.

Understanding the 2½ dimensional model

Now what exactly does this mean, and what are the implications? Rooms of a building are represented only by their outline as flat polygon objects. Each polygon object is defined by an ordered sequence of vertices. Each vertex however is re-presented through Cartesian coordinates as a triple of (x, y, z) values. The z value allows representing the room's height above ground level, so that multiple floors can be represented. Polygons can have several symbolic attributes, such as name, type, and accessibility for pedestrians. Polygons that are defined by vertices from two dif-ferent levels represent connections such as ramps, stairs or escalators. Figure F (left) shows an example, where the polygon "Corridor.14021" is defined as sequence of vertices with index (1, 2, 3, 4, 5, 6, 7, 8). In order to allow for route finding it is important to know the semantics of connections between polygons. Thus each edge is attributed by their passability: edges that represent walls or windows are set to be "not passable", in our example edge (8, 1) represents a wall; edge (6, 7) connects the corridor with the adjacent staircase and is annotated to be "passable for pedestrians". On the right hand side in Figure 1, a sample path is shown that has been calculated based on start- and ending points within the 2½ dimensional location model.

Based on the outlines of the rooms and some additional annotation of type and height, *YAMAMOTO* automatically creates the building structure in full 3D. By using the predefined building blocks shown in Figure 2, edges can be visualized in the perspective views as walls, doors, murals or handrails.

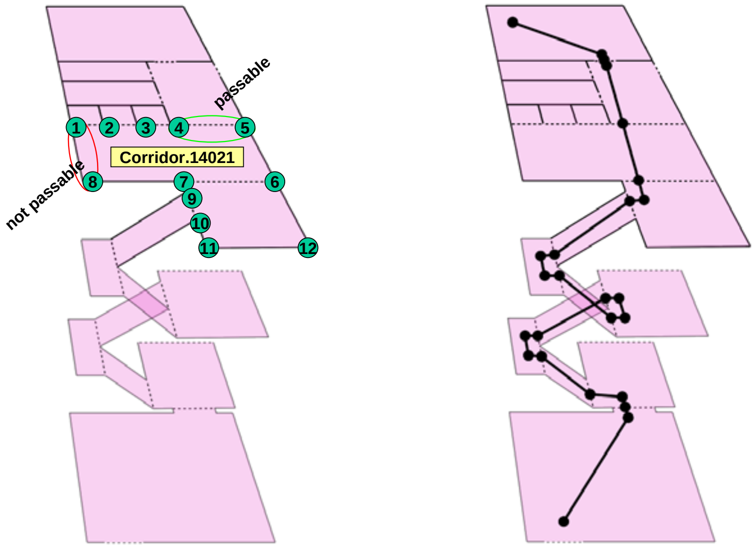

Fig. 1. The 2½ dimensional data model (left) and a route between two points (right).

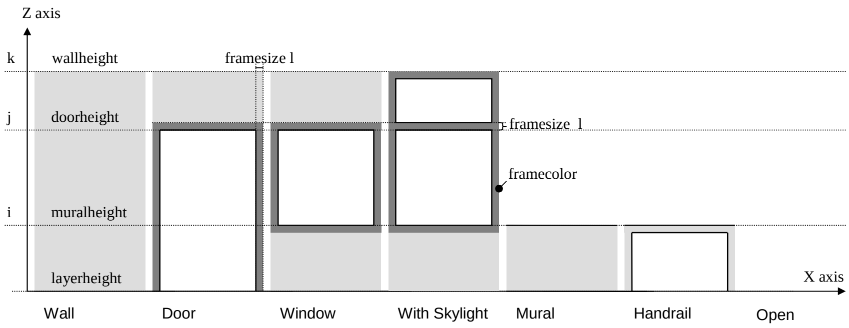

Fig. 2. Set of building blocks, used to automatically create 3D geometry from the 2½D model.

Allocentric and Egocentric Perspectives

One can choose in *YAMAMOTO* at any time among different viewpoints. The orthogonal view shows a top-down projection of the model similar to traditional maps. The perspective view shows the model from an allocentric viewpoint outside the model, as seen in 3a), and allows for free rotation and zoom. The user itself can be virtually represented in the model through an avatar object. The egocentric perspective shows the model from the viewpoint of this avatar, see 3b). It allows for the virtual exploration of the modeled environment. It also creates a demand for interior items that could serve as landmark objects for route descriptions. Rooms can be equipped with predefined 3D objects like shelves, tables or pictures, as seen in 3a) and 3b). Furthermore, one can instrument the environment with pervasive computing artifacts, i.e. beacons used for indoor positioning/navigation and public displays. The avatar view lets the designer virtually examine the visibility of the displays from various positions and helps to identify the best configuration, as described in [3]. In particular the possible interpretation of graphical signage, e.g. an arrow pointing upward, can be ambiguous depending on the actual context of the building. Such situations can be virtually evaluated and resolved before the signs are deployed.

Fig. 3a. Allocentric perspective

Fig. 3b. Egocentric perspective

Results

In order to assist pedestrians in their wayfinding tasks, we have used *YAMAMOTO* to automatically generate visual route instructions for public displays. We have conducted a user study with fourty-eight subjects and compared their performance under three different conditions: (1) floor maps, (2) a sequence of 3D pictures of decision points, and (3) an animation that shows the movement through the virtual building from the egocentric perspective. As a preliminary result, considerably fewer errors have been made by the subjects who saw the animation [1]. Presumably it is easier for the subjects to memorize the turning information through the movement of the virtual camera in comparison to static, symbolical information, such as arrows.

References

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