Smart Graphics in Adaptive Way Descriptions

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ABSTRACT

While car navigation systems are widely commercialized already today, pedestrian information systems are still in the early research stage. However, recent progress in mobile computing has opened perspectives for pedestrian navigation systems. In this context, graphics is and will still be an important modality to convey all types of route information. This paper will address the question how to generate graphics for navigation systems that help pedestrians, e.g., airport passengers, city tourists or conference attendees, to find their way in complex environments. We will discuss how the presentation of graphics can be tailored to various technical and cognitive constraints, and we will demonstrate our ideas within a scenario where a passenger of an airport gets navigational help from a stationary info booth and afterwards on her way via a handheld device (PDA). Both the 3D visualization at the info booth and the sketch-like presentation on the PDA are generated from the same data and by the same system, yet are adapted to the specific situation, output medium and user as far as possible.

1. SCENARIO

In the project REAL, we investigate the design of a resource adaptive navigational help system with the capacity to adapt to various restricted resources (cognitive or technical) during the generation of multimodal route descriptions. The resource adaptive generation of graphics/animation for different classes of output devices implies dealing with limited technical resources on one hand, and taking into account a user's limited cognitive resources to decode and understand the presentation on the other. The upper end of the scale is represented by a 3D walkthrough guided by a virtual scout accompanied by spoken or written text and meta graphics complementing each other, possibly using multiple viewports, while the lower end is represented by simple sketches of the environment and arrows indicating the direction. In this paper, we will concentrate on the generation process for the design of these vastly different types of presentation from a single knowledge base.

In addition to stationary information booths, we are also considering information presentation for mobile systems, such as PDAs with limited technical resources. At the information booth, you will obtain the display application for your PDA over an infrared connection, make choices where you want to be guided, or what kind of information you are interested in additionally.

The presentation has to be tailored to these devices' limited display capacities by generating route descriptions in a simple sketch-like form. After leaving the booth, the PDA filters the corresponding information out of a data stream broadcast by infrared transmitters spread throughout the building. The underlying protocol we developed guarantees a fast availability of simple or abstract information, while more details are accumulated as the user stays within the range of one transmitter [3]. A passenger in a hurry might only see an arrow pointing in the direction of her destination, while someone pausing at a place will soon have an environment map available with additional information about shops or restrooms.

The construction of a presentation involves at least the following steps: determination of the information to present, determination of a presentation structure, graphical realization of the actual presentation. In addition, the information has to be presented taking the maximum benefit of particular strengths of each presentation medium, taking into account the actual content as well as the current environment/context. We'd like to focus especially on

- limited resources on both sides of the communication channel, i.e. technical limitations of the sender (computer) and cognitive limitations of the receiver (user).
- variable resource restrictions that are unknown in advance and are coming up during the planning process or during the presentation.

Figure 1 shows some of the graphical techniques that we use for the visualization of way descriptions, including both static images (as the sketches on the left) and animations (e.g. a walkthrough from an ego perspective). The further

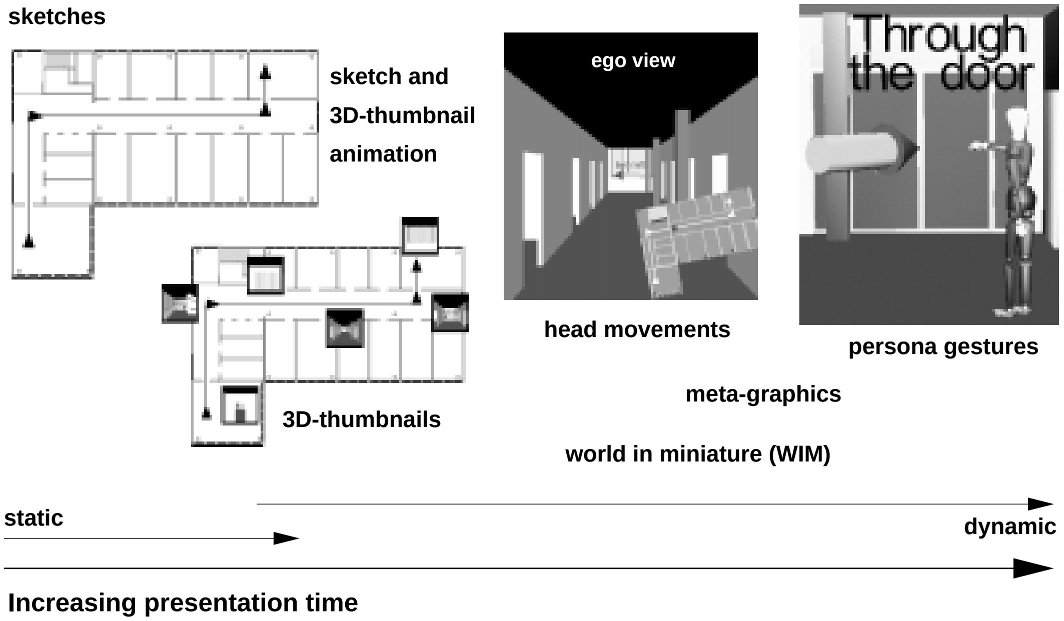

Figure 1: The upper part of the figure shows different techniques for path visualization ordered by the required amount of presentation time.

right a technique is displayed in figure 1, the more time is needed by the system to successfully present the information. But the main assumption is that a guided walkthrough with a persona leads to a better memorization of the way description. Our main goal is to generate these different presentations for the same way description from the same data, i.e. a 3D-model of the domain and additional structured information (e.g., about landmarks and the route graph).

2. LIMITED RESOURCES

As we assume that graphics are always used to communicate content between a sender and a receiver (in this case the machine and the user), the goal is to design the graphics as appropriate as possible for the given situation. We don't want to discuss general issues of automatic graphics generation in this paper, but rather concentrate on limited resources of the viewer and the machine, and what consequences these limitations bring. Whenever graphics are presented via a certain medium to a human viewer, two different types of resources play an important role: on one hand all the *technical resources* of the machine and on the other hand the *cognitive resources* available to the user. Technical resources cover all types of limitations to the presentation platform. Two different subtypes can be identified: Restrictions of the output medium and restrictions of the generation process.

The output medium is the visual interface to the viewer. Typical output media are printed paper and computer displays, but also 3D-displays, such as stereo glasses. All these media are at least restricted by the *inner* and *outer* scale. These terms from cartography describe the maximal size of the displayed graphics and its resolution (and thus the amount of detail that will appear). Both factors influence the presentation of the same graphics. For example it's not possible to infinitely reduce a graphics' size without loosing important details. If the outer scale of the display is limited, it might be better to enlarge some smaller details that are important and omit others which are not so relevant for the visualization task. Another limitation is *color*. Colors often provide important information about the depicted objects. Color can also help to focus on important objects or details (e.g. a red spot near the objects of interest) If color is not available the system has to convey this information by other means or omit it completely.

The graphics generation process itself also needs resources, especially *cpu-time* and *memory*. These are often critical in realtime applications, such as the scenario mentioned in the beginning, where a complete way description has to be rendered and displayed for a hurrying passenger. One of the most important cognitive resources of the viewer is her *working memory*. Following [2] the working memory does consist of at least three components: an attentional component, a phonological loop and a monitoring central unit. In this work we simplify the limitations that are connected to the working memory of the user to three classes of parameters: *time restrictions*, *domain knowledge* and *familiarity* with the presentation type.

Time restrictions can be divided into two different types. The *viewing time* is the time the viewer is given to look at the graphical presentation. In contrast to this, *decoding* time describes the time the viewer needs to decode the presentation and understand it's meaning. Both times may be very limited, especially when the viewer is heavily stressed.

Graphical presentations and a system generating them can respond to limited resources in various ways. For our work, we differentiate the terms resource-*adaptive*, resource-*adapting* and resource-*adapted*. A resource-*adapted* process would, for example, make optimal use of a given medium under given circumstances. In order for a process to be called resource-*adapting*, it will have to react to known resource limitations yielding lower quality or different results. A fully resource-*adaptive* process will react to upcoming resource limitations during run-time and might even totally change its strategy in order to still yield results under the new restrictions.

3. ADAPTIVE PLANNING OF WAY DESCRIPTIONS

In order to generate structural descriptions of the graphics we have extended an efficient hierarchical planning approach presented in [4] for the generation of 3D animation. The main assumption here is that all generated graphical presentations can be structured in the form of a tree describing parts and subparts of the graphics to a certain depth. Each part or subpart corresponds to a node in the tree. Nodes are either terminal nodes in which case they describe portions of the graphics that will be realized by one of the graphics realization techniques described in the next section, or they are nonterminal nodes, in which case they specify a set of subnodes and a logical, spatial or temporal interrelationship between them.

Temporal interrelationships only apply to temporal media and include the concepts *parallel*, *sequential* and *incremental*. An example for temporally *parallel* subparts of a graphics are, for example, a camera motion and an object motion taking place over the same timespan of a 3D animation. A *sequential* interrelationship describes a sequence of subparts taking place in a temporal order, e.g., one after each other. Specifying the subparts as having an *incremental* relationship means that after a subtree is fully expanded, this subtree can be forwarded to the graphics realization component, which is not the case with every subtree in a *sequential* list. The specification of incrementally ordered subsequences allows the graphics realization process to start its work before the structure of the graphics is fully generated, and thus greatly reduces the perceived delay from the start of the whole graphics generation process to the moment the first graphical element is shown.

Spatial Interrelationships include a limited set of spatial orderings, such as *left-to-right* or *top-down* and can be used to roughly arrange visual elements such as viewports on a screen or parts of a composite graphics or diagram. In this sense they can be used within both temporal and static media and allow a rough specification of the overall spatial layout of the presentation. This is only a very coarse specification for higher levels of the presentation structure and should not to be confused with spatial arrangements of objects within a camera window or low-level elements of a diagram.

Logical interrelationships include the concepts of *alternative*, *conditional* and *additional* subtrees in the structure of a graphical presentation. Both *alternative* and *conditional* subtrees specify a list of possibilities for the realization of a certain part of the graphics. *Conditional* expansion selects one alternative from this list at planning time. In this way we can, for example, specify that a certain type of graphical presentation can be generated either as a line drawing or as a 3D image of the scene depending on media restrictions. Specifying these subtrees as *alternative* postpones the decision until presentation time. The strategy here is to first expand the structurally simplest or computationally cheapest part of the tree and then – if time permits – to proceed with more complex alternatives that might be visually more appealing or clearer in the communicative sense. The resulting structure graph contains all of the various alternatives (unless planning was stopped before due to temporal restrictions) and leaves the decision which alternative is chosen to either the presentation process or even the user.

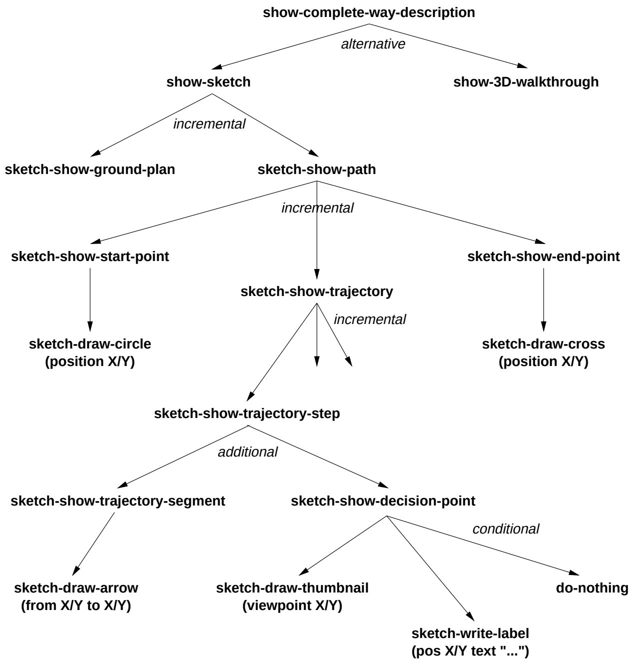

Figure 2: Simplified example of a structure tree for a graphical representation description

An example for an *additional* relationship between subtrees of the structure tree is the labeling of a line drawing or the creation of additional viewports for an already running 3D animation. This assumes that already the first subtree would yield a 'working' graphical presentation, while the following subtrees contain presentation elements which will enhance the overall quality of the graphics.

As it might have become obvious, the different kinds of interrelationships within the structure tree of a graphical presentation leave room for various strategies of adaptation of the generation process to limited resources either in the output medium or in the generation process. They allow the resource-*adaptive* generation of resource-*adapted* (decisions at planning time) as well as resource-*adapting* (decisions at presentation time) graphical presentations (see section 2).

Figure 2 shows a simplified part of a structure tree for a graphical way description. At the root of the tree we see that the way description can be presented in the form of a sketch or *alternatively* a 3D walkthrough. One of these alternatives can be chosen at presentation time based on circumstances, media restrictions or user preferences. In the case of a sketch the ground plan and the actual path have

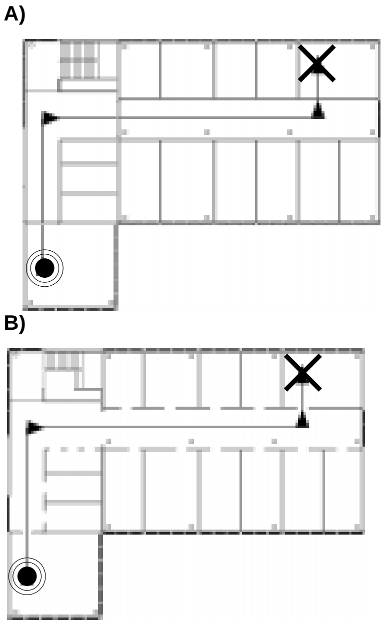

Figure 3: A sketch of the map is derived from the 3D-data (A) by choosing a bird's eye perspective and a parallel projection. Doors are made visible by clipping the 3D-model with the navigator's vertical extension, i.e. cutting it above the head and below the feet (B).

to be shown. Specifying these two actions as having an *incremental* interrelationship implies that the ground plan can already be drawn by the realization component while planning for the path visualization continues. Had we specified the two actions as being *parallel* or *sequential*, planning would have to be finished before the realization starts.

The visualization of the path itself consists of showing its starting and ending point and the trajectory inbetween. Showing the trajectory in turn is nothing else than an incremental loop over all of the trajectory's segments and drawing an arrow for each of them. Optionally, after drawing each segment of the trajectory, the corresponding decision point can be shown. Depending on media restrictions this visualization can consist of a thumbnail image from the 3D world at this particular point, a text label or nothing at all.

4. GRAPHICAL TECHNIQUES FOR PATH VISUALIZATION

This section describes several techniques hat can be used to generate visualizations of a path or trajectory under limited resources of the system and the viewer (see section 2). Which of the following techniques is chosen in a particular situation is determined by the planning process (section 3). At this point, the relevant objects of the scene are already determined and the graphical realization can begin.

First, we will discuss the graphical techniques that are customized to various cognitive loads of the viewer without looking at the technical limitations of the presentation system. This refers to the example of the aforementioned information booth that can supply the navigator with all kinds of information she might require, but is restricted to a complete way description. Afterwards we will have a look at graphics generated for a mobile device with very limited computational and expressive power (e.g. a handheld computer with a small black and white display). The main advantage of using the mobile device is the possibility to give incremental way descriptions and that the navigator can compare graphics and environment directly instead of relying on a recollection of the complete way description.

4.1 Sketch rendering

If time is critical, black and white sketches can be considered a good way to reduce the amount of available information to a minimum, presenting only the relevant details and thus focusing the viewer's attention on the important parts of the way description, i.e. the trajectory itself.

To generate a sketch version of the path is easy since it is already approximated by a number of points that can be connected with a line in different line styles, e.g., a dotted line with an arrowhead at the beginning and at the end (see figure 3). The visualization of the environment (consisting of several reference objects that help to localize points on the trajectory) in 3D-space is more complicated. The detailed 3D-objects that may serve as reference objects have to be displayed in a simple but comprehensible way. We rely on Non Photorealistic rendering techniques similar to the ones already introduced in [11; 10].

Instead of displaying all edges of a 3D-model (using the typical wire-frame mode) these techniques try to find the edges that are visually more important than others and use only those needed for the visualization of the object. Such edges can be determined by a certain threshold angle or by edges that divide a visible from an invisible polygon under consideration of the current point of view. Since our system knows about the goals of the viewer, it can include additionally (or exclude) particular details. Let's assume that a navigating passenger in an airport wants to buy a book along the walk to her gate but time is very limited. In this situation, a sketch is better then a lengthy animation showing the direct way from the current location to the gate. Nevertheless, bookshops on the way should be included into the graph, whereas all other shops should be oppressed. In order to get a real sketch resembling a floor plan from the 3D-model, a parallel projection orthogonal to the trajectory plane is chosen in which the 3D-model is clipped to exactly fit the avatar's size. This results in a visualization of those areas that can be reached by the avatar without bending or jumping (see figure 3). In addition different line styles (dashing, line thickness, grey value) can be used to emphasize or de-emphasize certain details of the graphics.

4.2 3D-thumbnails

The concept of 3D-views inserted at prominent points in a plan was first introduced in [6]. The idea is to use 3D-thumbnails to provide additional information of the environment at certain critical decision points. Although this leads to an increased complexity of the graphics, showing 3D-views at critical decision points presumably helps the viewer to memorize the route better.

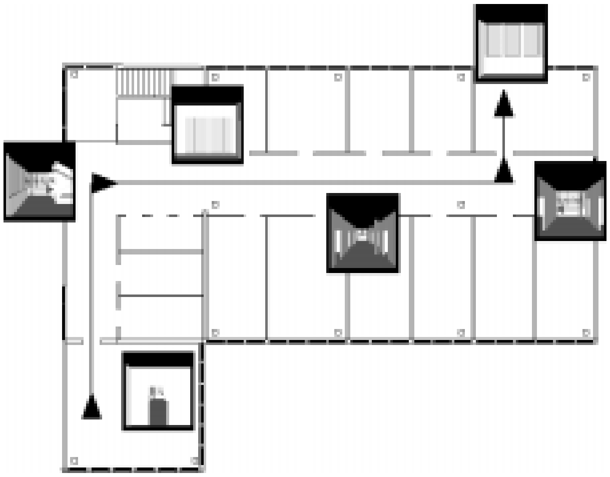

Figure 4: The sketch of the map is annotated with 3D-thumbnails that show the perspective view at selected locations along the route.

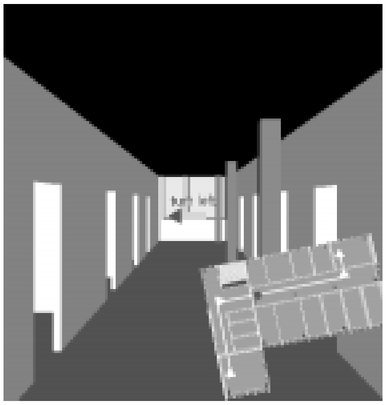

Figure 5: An animation showing the movement along the path taken from an egocentric perspective is a more natural way to visualize route information. A small world in miniature (WIM) with a marker of the actual position counteracts the loss of overview.

The images are taken directly from the 3D model from a position and an viewing angle that is determined by the assumed position of a navigator moving along the path towards the target. The 3D image is inserted preferably near the path in the 2D image near the position of the used viewpoint. The insets should be aligned to the display in order to ensure that the viewer doesn't have to rotate the 3D image (see figure 4). The overall problem of placing the thumbnails is very similar to layout and annotation problems on which a lot of work has been done over the last few years (see [7]). We rely on a simplified version of these algorithms and just place the images beside the path trying not to obstruct landmarks and other details that should remain visible.

4.3 Ego perspective and motion

If time is not so limited more elaborate visualizations of the path can be generated and presented to the navigator. This includes a walkthrough of the surroundings with the highest degree of detail. Empirical studies suggest that a path presented from an egocentric perspective can be memorized more easily than a simple map view. One reason for this is that the ego perspective (sometimes also referred to as *field perspective*) is the natural way to see the world. More realistic rendering techniques (textures, lights, shadows) and more geometric details support a better immersion of the navigator into the scene. The working hypothesis is that this leads to a better performance of the way finding task in the real world later on.

We're experimenting with different ways of path visualization that work with animated ego perspective and that differ in their complexity. The common ground is the movement of the viewpoint through the 3D scene along the trajectory segments. Similarly to the moving dot in the animated sketch described above, the movements of the persona should be smoothed at sharp turns to obtain a more life-like appearance. These movements can be computed directly from the trajectory. Smoothing is done with spline interpolation between trajectory points. Furthermore we use *head movements* and a 3D-persona to focus the viewers attention to important details (e.g., landmarks) along the route.

Head turns can be performed without interrupting the walk along the path resulting in a nested movement of the field of view. This is similar to the effect a person will experience in the real world when looking besides while walking straight on (see also [5]). In such a situation, problems may occur when the viewing direction differs too much from the walking direction. Therefore, it seems to be reasonable to slow down the overall walking speed during head movements to avoid irritations of the viewer.

The next step is the introduction of a 3D presentation persona (see [9; 8; 1]) that gives a guided tour along the path. Gestures (see figure 1) performed by the persona underline important details along the way. The movement of the persona can be used to highlight spatial configurations. Instead of taking the direct connection between two points the persona can emphasize a landmark by approaching it, trading a longer way for the chance to convey more information.

4.4 Graphics generation for mobile devices

Graphical path description on mobile devices differ from descriptions generated for a stationary information booth in at least one point. Since a mobile device can be taken along the way, it won't be necessary to give a complete way description in advance. Incremental descriptions for the actual path segment are usually sufficient. Of course, the device has to be aware of its current location to some extent. In our scenario we rely on infrared senders that are placed along the path. For each region of the path that is in reach of a certain infrared sender the corresponding way description is broadcast to the device (for a more technical discussion of this issue see [3])

Figure 6A shows a simple example of an arrow, telling the navigator to go straight ahead from her current position. The direction of the arrow can be derived directly from the orientation of the current segment. Sometimes it might also

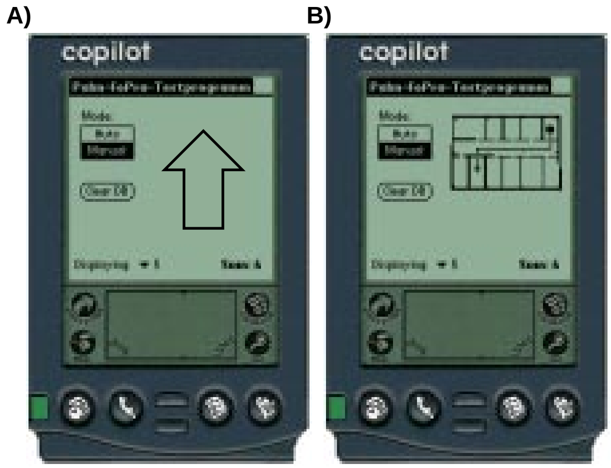

Figure 6: Incremental way descriptions on a mobile device can be reduced to a minimum, since the navigator is in the real world environment and doesn't have to rely on memorized information (A). Complete way descriptions have to be much simpler due to the low resolution and color capabilities of the display (B).

desirable to give context information for the current position. Due to the limited resolution of the display only very simple sketches of the surroundings can be used (see figure 6B). We believe, however, that the possibility of the navigator to match the graphical presentation with her actual environment compensates this loss of information.

5. CONCLUSIONS AND FUTURE WORK

In this paper, we have shown methods for the flexible and adaptive generation of graphical presentations in the domain of way descriptions. After presenting the scenario and a short discussion of resource restrictions, we have discussed how to partition way descriptions appropriately, how to plan a structural presentation for the graphics and how to create the actual graphics from this structure. We have shown that it is possible to generate a wide variety of graphical presentations from a single 3D object and knowledge base. These presentations range from arrows or simple line sketches for location-aware mobile devices to complex 3D-animations with multiple viewports that can be used at stationary information booths.

While some aspects of our work, such as sketch rendering or hierarchical planning have been introduced before, we believe that it is essential for intelligent presentation systems to integrate these techniques in a comprehensive framework and to adapt all aspects of their presentations as well as their presentation planning process itself to the available resources, be they constrained by limitations of time, output media, or the amount of information a user can process in a given situation. Our approach adapts the whole graphics generation process to these resource limitations and generates graphical presentations that try to make optimal use of the communicative channel.

We are currently preparing an installation of our PDA-based navigation and information system for two large booths at the German computer fair CeBit 2000 in Hannover. From this field test, we hope to gain new insights on its real world usability and further refine the presentation strategies and graphics realization methods. In addition, we have started to build a wearable computer system using a GPS and a head-worn display for the exploration of our graphics generation strategies in an outdoor scenario.

6. ACKNOWLEDGMENTS

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