Multi-Media Map for Visual Navigation

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Abstract

Navigation using visual aids has always been an important skill for any navigator. One of the most important visual aids on land and along the coast is landmark. Traditional cartography has developed many techniques in representing landmarks on a map, including hill shaind, symbology, and perspective drawings. One of the problems in using a traditional map, which is an orthogonal projection of the land features, is that its "air-perspective" does not match the "ground-perspective" of a navigator on land. In this paper, we will discuss the role of landmarks in navigation, the use of photographic images to represent landmarks, and the development of a prototype for visual navigation using a multi-media map.

1 Introduction

One of the popular applications of maps is to find one's way either along a pre-defined route or in an exploratory mode following rather ad-hoc paths. The ultimate objective is to not get lost, meaning that the traveller should know exactly his or her position at all times. This is the problem addressed by the age-old science of navigation, which was initially used to direct a craft by determining its position, course, and distance traveled [Britannica, 2000]. At the core of the problem is to position (know where you are) and to orientate (know where you are going). The lack of visual landmarks in open sea and space has led to the development of a wide range of positioning devices (such as the sextant and later GPS receivers) and orientation devices (such as the compass).

Navigation on land is faced with the same problems confronting the sea and air navigators. A marked difference here is the vast amount of visual marks on the ground available for positioning and orientation. Although the same devices such as GPS receivers and compasses can be used for land navigation as well, most navigation on land do not employ sophisticated aids because they are too expensive, too cumbersome, or too complicated. A map and the landmarks in the neighbourhood are likely the only aids available to a traveller on land, particularly if the traveller is going around on foot in an urbanized area.

Even when sophisticated positioning and orientation aids are being used, travelling on land is much more restricted than travelling on the open sea. There are certain roads and paths the traveller must follow. Hence a general direction indicated by an orientation device such as a compass must be refined by matching it with the appropriate path on the ground. A very useful aid for refining the direction is again landmarks.

In this paper, we will discuss the use of landmarks for land navigation and methods of incorporating them in a digital map.

2 Experiments on Visual Navigation

Research on visual navigation has been scantly. We have found three studies comparing different visual aids for land navigation. The three studies concentrated on the use of maps, audiotapes, films, verbal descriptions, and road signs.

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Goldin and Thorndyke [1982] investigated and compared actual navigation and simulated navigation as a source of environmental information to aid way finding. Subjects were toured in an unfamiliar area in Los Angeles either in a bus driven along an 8.3 km of the area or indirectly by viewing a film taken from inside of a car travelling along the same route. The first group is called the tour group and the second group is called the film group. Within each group, the members were further divided into three subgroups provided with different kinds of supplementary information. The verbal subgroup was given verbal description, the map subgroup was given a map to study ahead of time, and the control subgroup was given nothing. Subjects were tested after the tour on three types of knowledge about the environment: landmark knowledge, procedural knowledge, and survey knowledge. Landmark knowledge refers to "memory for salient perceptual features in the environment." [Goldin and Thorndyke, 1992] It is a test on the ability to recognize landmarks encountered before. Procedural knowledge refers to "knowledge of specific routes navigated in the environment." [Goldin and Thorndyke] Having procedural knowledge is having knowledge of the path usually acquired and retained in a sequential manner. Survey knowledge refers to "the two-dimensional configurational relationship among location." [Goldin and Thorndyke, 1992]. Such relationship between two locations "may be apprehended without reference to any particular route between them." [Goldin and Thorndyke] Having survey knowledge is having knowledge of the environment in a general sense unrestricted to any specific path.

Subjects were required to explore the environment as much as they can without any guidance and restriction, then they were asked to walk a given path. In the landmark knowledge test, subjects were tested whether they recognized certain landmarks. In the procedural knowledge test, subjects were tested on the sequence of features encountered, distance between location, and orientation between some turning points. In the survey knowledge test, subjects were asked to estimate a straight distance between pairs of location, to draw a map of the test environment, and to place several landmarks in their correct position.

The result showed that within the film group, the map subgroup performed similarly as the control subgroup, while the control subgroup performed better than the narrative subgroup. The overall result of the film group was better, and this can be explained by the availability of pauses in the film tour when landmarks were encountered. Subjects would hence pay more attention on the landmarks shown. The film group concentrated more on the visual details than the tour group since images shown on the film were planned and focused along the path only. Subjects would not be sidetracked by other irrelevant road details.

Streeter et al. [1985] compared the different aids to help navigating a car along a given route. Each subject was asked to drive along an unfamiliar test area as one of the following four groups. The first is the map group given standard and customized route maps. The second is the tape group given audio directions. The third is the map-plus-tape group given both map and tape. The fourth is the control group allowed to choose whatever tool desired. It was found that those in the map group and the map-plus-tape group preferred customized maps to standard road maps. The use of tape was generally preferred to customized maps. Among the four groups, the use of tape for instruction was highly preferred. The second preference was to use both map and tape for instruction, while the third preference was to use maps only. With reference to the overall performance, tape instruction produced fewer errors and required less time for path finding.

Butler et al. [1993] performed wayfinding studies in one of the buildings at Ball State University. Subjects were asked to go from the sign-up board to the laboratory. The experiment compared the use of pure verbal guides, sign systems, and schematic maps. For the verbal guide test, subjects were given verbal descriptions by the secretary on the path to follow. For the sign system test, signs were placed along the path. For the schematic map test, a you-are-here map was placed at the starting point.

The results of these experiments showed that pathfinders who were given just verbal directions required a longer time to associate the environment with the description, and it was particularly difficult to recollect the description if the building was complex. Besides, the results showed that the sign system was relatively more effective than the you-are-here map. Pathfinders were only required to follow the signs leading directly to the destination without reference to any supplementary information.

An independent study conducted at the Polytechnic University has confirmed the usefulness of visual navigational aids on land. The experiment asked test subjects to follow a path captured by a sequence of pictures along the path and at intersections. Pictures annotated with the path or marked with turning directions were found to be most useful. A problem that were encountered by some users given only sequential photographs not supplemented by a map is that the users did not have a good idea of the distance between photographs. This forces the user to look out for matching landmarks all the time along the path, leaving very little time for anything else. This problem could be partly solved by providing photographs only at intersections, given that both the photographer and the user understand what an intersection is. This finding indirectly points to the desirability of combining photographs with a map so that the marked location of where the photographs were taken gives a sense of distance between photographs. Moreover, the sequential photographs would be of very little help for someone whose has lost the way.

What we can conclude from these findings is that landmarks are very important visual aids for navigation. The closer the images of the landmarks on the map match those on the ground, the better they serve the purpose of navigation.

3 Landmarks for Navigation

The importance of landmarks for navigation has been long recognized. A landmark, being a conspicuous object on land that marks a locality, can be anything at all. The keyword here is “conspicuous”, which bears more of a relative than an absolute sense of importance. For example, a low rising object against the sky could be more conspicuous than a high rising one against the backdrop of a mountain. In reality, almost any kind of “mark” on “land” is a potential landmark, their usefulness depending on the speed of travel and how observant the traveller is.

Over the years, traditional cartography has developed many techniques in accentuating landmarks. Examples are hill-shading, symbology, perspective drawing, and annotation. Although these methods are effective under different circumstances, the map being an aerial view of the land is not the best perspective for navigators on the ground. A hybrid-perspective approach is often used to resolve the differences between aerial view and ground view. Examples of this approach abound in historical maps (Figure 1), and this technique has often been applied to modern tourist maps (Figure 2).

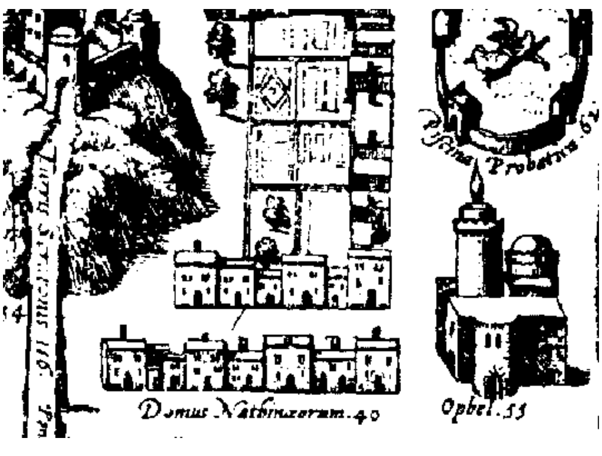


Figure 1: Part of a map of Jerusalem in the *Civitates orbis terrarum*, vol. IV in 1588 [Skelton, 1965].

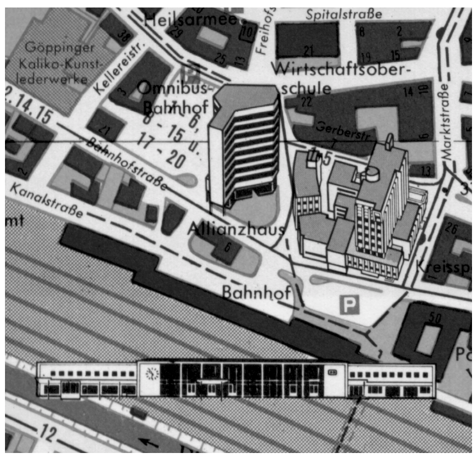


Figure 2: Part of a German map published in 1969 [Deutsche, 1970]

The use of perspective drawings of buildings (or any structure with a rather small footprint on the map) to show landmarks is quite effective for the urban traveller. A problem with this method, due to the static nature of the paper map, is that these perspective drawings tend to block the map behind it. Another problem is that these drawings can only be viewed from a fixed direction, making orientation from another approach rather difficult. Moreover, this method is not very useful in the open country where landmarks such as mountain ranges occupy very large footprints.

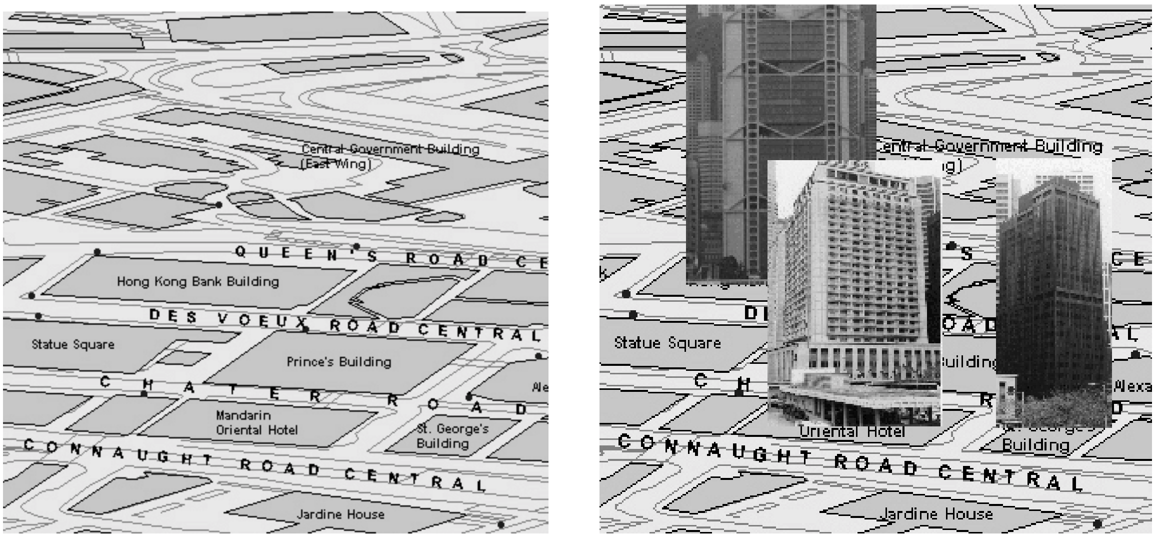
Experimental tests, as well as our own experience, have shown that orientation using landmarks is most effective when the ground view matches the map view. With this in mind, we have developed a prototype land navigation system offering a number of visual aids. The digital environment allows us to provide a close match between the ground view and the map view.

4 Visual Aids for Navigation by Landmark

In this section, we will describe a number of visual aids that we have found useful in helping a traveller navigate by landmark.

4.1 Perspective Map View

A perspective map view (Figure 3) is a projective transformation of the orthogonal map view. The perspective centre will be towards the heading of the traveller. This will bring the perspective of the map closer to that of the traveller thus making the matching of landmarks easier.



(a) A Map in Perspective View

(b) Perspective Map with Landmark Photographs

Figure 3 Perspective views of maps, with and without landmarks

4.2 Perspective Map View With Landmark Photographs

A three-dimensional model of the landmarks would have been ideal for navigational purposes (Figure 4). However, these models are very expensive to create and to update. We find that ground photographs of the landmarks serve the same purpose at only a fraction of the cost.

A series of photographs for the same landmark will be captured from different angles and associated with the city block or location at which the landmark is situated. The number of photographs required for a landmark depends on the number of potential approaches towards it, typically one from each road leading to it.

4.3 Panoramic Photographs

A panoramic photograph covers a full-circle view around a location (Figure 5). A particularly innovative implementation of it was first developed by Apple Computer resulting in an extension to its popular QuickTime software and is called the Virtual Reality QuickTime (QTVR) [Apple, 2000]. That idea has since been used by other developers to produce similar software.

The idea of QTVR is to allow the playback of a full-circle panoramic photograph in an interactive mode. Instead of the normal QuickTime interface, which is basically a passive display of a movie clip, QTVR allows the user to pan around a panoramic photograph. This creates the illusion of looking at the scenery around a point. QTVR also supports hotspots on the panoramic photograph for linkage to still pictures, text, sound, and video clips.

Figure 4: 3-D Model of Landmark

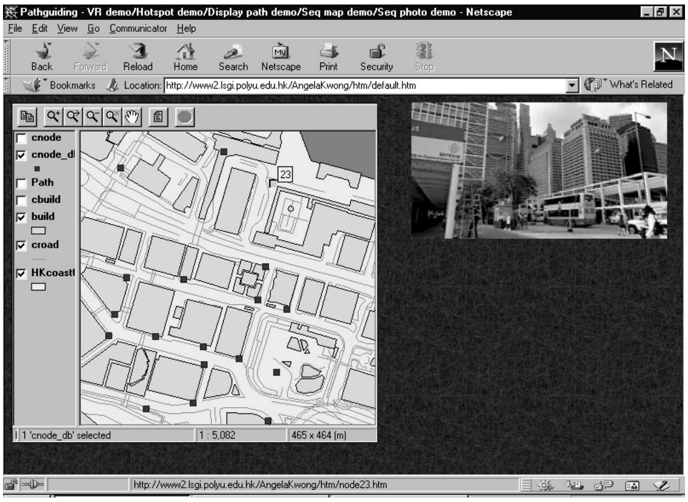


Figure 6: Integrating a Panoramic Photograph With a Map

The ability to pan around a panoramic view and matching it with a map view, either orthogonal or perspective, is most useful for navigation using landmarks. Intersections are critical places for travellers navigating along a network of roads. The panoramic photographs are particularly useful for orientation at the intersections. Figure 6 shows an integration of a panoramic photograph with a map.

Figure 5: Full-Circle Panoramic Photograph

This approach is complementary to that of using multiple photographs around a landmark. In the first case, we cover a landmark with several photographs around it. In this case, we take several photographs around a node and stitch them together to form a panoramic coverage. The form case is suitable for landmarks with a small footprint, while panoramic photographs are suitable for landmarks that cover a large footprint. QTVR can handle an inverse "panorama" around an object, thus allowing the viewer to virtually turn an object on the display. It is rather difficult, however, to cover a real-world landmark with these inverse panoramas.

4.4 Sequential Static Photographs

A series of static photographs is sometimes more useful than an interactive display for navigation (Figure 7), particularly if the navigator is also busy driving a vehicle. Using this technique, a series of photographs will be taken along a pre-defined route at strategic places, such as at intersections. These photographs will then be displayed on a terminal or simply printed on paper to aid navigation. If the navigator has some knowledge about the area along the path, it might be necessary only for the navigator to briefly consult the series of photographs before starting the trip.

Figure 7: Sequential Photographs Along a Path

5 An Implementation of a Prototype

We have used a Web-based platform to produce a prototype for a system to aid visual navigation. This system combines the ideas mentioned above into an integrated package so that the user can choose the most appropriate aid for the situation.

A Web-based platform has the advantage that it can be used either online through a network or offline from the hard-drive or a CDROM. The platform chosen was Autodesk MapGuide. The Autodesk MapGuide basic system architecture consists of the Autodesk MapGuide Server, Autodesk MapGuide Author, and Autodesk MapGuide Viewer for Web browsing. The visual aids such as QTVT movies and landmark photographs stored as HTML pages on the MapGuide server.

The implementation itself is quite straightforward. The base map in vector form is imported and linked to the navigational aids through hotspots. Figure 6 and 8 show the interface provided to the user. In a typical application, the user would first select a path to follow on the map (Figure 7). The system can then generate a list of sequential photographs, landmark photographs, or panoramic photographs as the user navigates along the path.

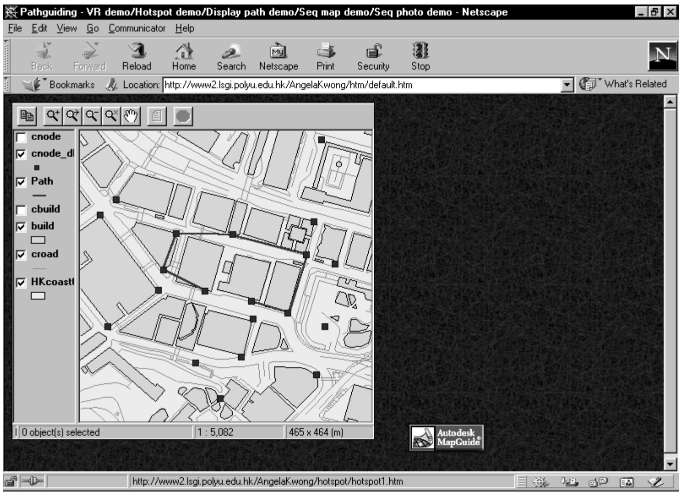


Figure 8: A User-Defined Path

6 Evaluation and Challenges Ahead

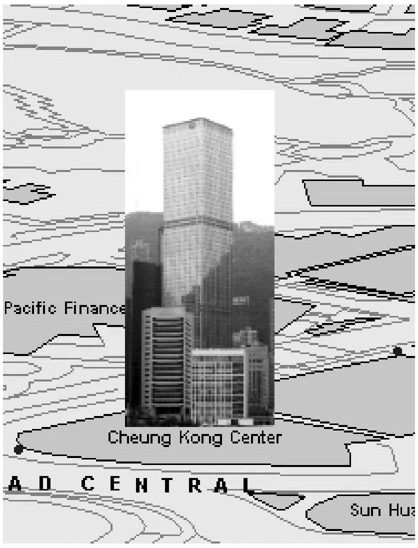
We have presented an approach to visual navigation and an implementation of a prototype to test the idea. In this section, we will describe our experience, evaluate the approaches being used, and identify the challenges ahead to make visual navigation a reality.

QTVR is now quite a mature technology being emulated by different developers. It has, however, remind chiefly a Web-based technology that yet to find its way into mapping software. Although it is possible for most mapping software to link to the QTVR as an independent players, but there is usually very little interaction possible between the player and the application software. One reason for needing such interaction is to establish an even better linkage between a panoramic photograph and a map by showing the direction of view on the map. On another project [Lee and Mack, 1997], we have shown the use of Director and QTVR for this purpose (Figure 9). A similar approach is also demonstrated in another Web-based tourist application [Virtually Vancouver, 2000]. Although Director is animation software, it provides a certain amount of graphic functions to create a map in raster format. The application programme interface between QTVR and Director can return the direction at which the user is pointing us while panning around the panoramic photograph.

Figure 9: Map with Arrow Showing View Direction

The approach using MapGuide provides more intelligent graphics in both vector and raster formats and a database for more efficient data storage and query. However, the linkage between the QTVR movie and MapGuide is not as good as that with Director.

Although preliminary tests confirmed the usefulness of the proposed visual aids, there are a number of challenges ahead. One of the difficulties we face is in the production of landmark photographs. A truly effective landmark photograph should show only the image of the landmark with a transparent background and foreground buildings removed. A transparent background allows the landmark behind it to show through. Foreground building if shown on the same picture of a landmark is spatially wrong and could confuse the user. For example, in Figure 10, the landmark photograph shows the landmark and a number of building in front it. If we place this landmark picture over a particular city block on the map, it would give the wrong impression that all the building shown are in the same block. This is a problem caused by the method used to photograph the landmark. To eliminate the foreground buildings, we would have to take landmark pictures at close range, a more difficult task for very tall buildings in a metropolitan area. Methods of taking multiple shots of a tall building from the ground and stitching them together to form a single image with perspective distortions removed is currently under investigation.



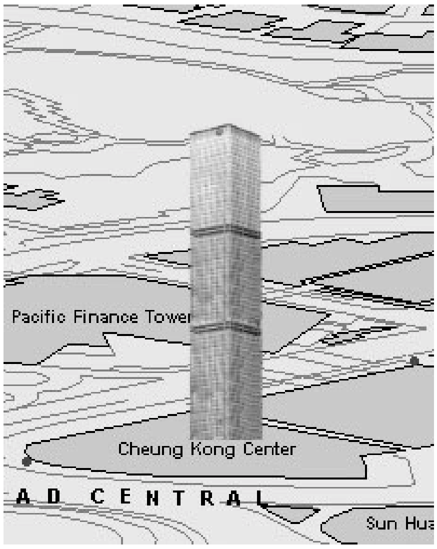


Figure 10: Problem with Landmark Picture and Its Solution

The technique of taking photographs around a point and stitching them together to form a continuous panorama is well developed but time consuming. Several novel techniques have been developed to simplify the process. One of them involves a digital camera integrated with software to stitch and produce a full-circle panoramic picture (Figure 11). A more radical solution uses a convex mirror in front of a normal camera to take a near hemispheric picture in one frame, which is then converted to a strip panoramic picture (Figure 12).

Figure 11: e-Pan Digital Camera [e-Pan, 2000]

An interesting extension of the panoramic image is a stereo version of it [Mars Pathfinder, 2000]. A stereo panorama is particularly useful for a user to point at a location on the panorama and obtain its two- or three-dimensional location on the ground so that attributes at that location can be retrieved from a spatial database. This is a rather challenging project for terrestrial photogrammetry being investigated at the University of New Brunswick.

Figure 12: Single-Frame Panorama Converted to a Panoramic Photograph [Charles, 2000]

We have emphasized here the use of visual aids in navigation for human. It is easy to extend the concept proposed for automated navigation by a robot equipped with a video camera and scene analysis capabilities. This kind of “visual” navigation would be useful under circumstances where satellite positioning systems fail, such as under tunnels for mining applications. These techniques are also useful to supplement satellite positioning by providing an additional visual check (either manually or automatically) to confirm the position.

7 Conclusions

In this paper, we have identified landmark as an important visual navigational aid, particularly for travelling on land or along the coast. For landmarks to be used effectively with a map to aid navigation, the landmarks and the map should be presented in about the same perspective of that of the navigator. We propose in this paper a technique of combining photographic images of landmarks with a map in perspective view. This reduces the time it takes to capture landmarks on the ground and to represent them in a digital database. A map in perspective view is closer to the perspective of the landmark image and to the navigator on ground.

For landmarks with a small footprint, such as buildings and monuments, their photographic images can be linked to their location on a digital map. If a landmark can be approached from different angles, a photographic image of the landmark will be stored for each approach. Depending on the orientation of the map, an approach image of the image will be selected by software and displayed with a perspective map. For landmarks with a large footprint, such as mountain ranges, a panoramic photograph taken at strategic intersections covering the landmark will be used.

The combination of landmarks (in both single image and panoramic form) and a map (in different perspectives) offers various methods to aid navigation. Other than the interactive display of a perspective map combined with the landmarks, a sequential sequence of pictures en route can also be generated.

The idea appears to be effective from our tests. Photographic images, which can be captured on the spot with little effort, is an effective alternative to 3D modelling. Together with a positional system, it is possible to develop a handheld navigational device incorporating the proposed idea to produce an effective portable tool. We can see an extension of the idea proposed in the paper in position measurement on panoramic photographs and on the automated guidance of vehicles along a pre-defined path.

Acknowledgements

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