Improving Web Navigation using Defined Perimeters and Landmarks
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Project Summary

The aim of the project is to improve navigation on the World Wide Web using defined perimeters and landmarks. The project begins by exploring the common problems faced by those wishing to navigate the WWW. It goes on to review the research already done in the area, specifically in work related to website perimeters and landmarks. Various solutions are considered and two navigation aids are described, implemented and evaluated. These solutions are a thermometer-style depth indicator and a landmark scheme using colour assignments. Experiments are performed using participants from the School of Computing and the results are presented and discussed. The results reveal the solutions demonstrate an improvement over a control condition where no navigation aid is present; in one case the improvement is significant, in the other further testing is required. The limitations of the evaluation are discussed and the project process is reflected on.
Acknowledgements

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# Table of Contents

Project Summary  
Acknowledgements  
Table of Figures  

## 1.0 Introduction to the Problem

1.1 Aim of the Project  
1.2 Minimum Requirements of the Project  
1.3 Evaluation Criteria  
1.4 Initial Project Plan  
1.5 Introduction to the problem of navigation on the WWW  
  1.5.1 The Nature of the Web  
  1.5.2 Lack of Context Information  
  1.5.3 Poor Design  

## 2.0 Background Research

2.1 Introduction  
2.2 Navigation using Landmarks  
2.3 Landmarks in Virtual Environments  
2.4 Navigation on the Web  
2.5 Website usability  
2.6 Methods of improving navigability on the WWW  

## 3.0 Designing of Solutions to the Problem

3.1 Selection of Possible Solutions  
3.2.2 Description of Chosen Solutions  
  3.2.1 Thermometer-style Depth Indicator  
  3.2.2 Landmarks using Colour Assignment  

## 4.0 Implementation of Solutions

4.1 Designing the Control Condition  
  4.1.1 Implementing the Control Condition – Division of Work  
  4.1.2 Details of the HTML-builder program  
  4.1.3 Structure of the Website  
  4.1.4 Screenshots from the Control Condition Website  
4.2 Thermometer-style Depth Indicator
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 Implementation of Solutions (continued)</td>
<td></td>
</tr>
<tr>
<td>4.3 Landmarks using Colour Assignment</td>
<td>23</td>
</tr>
<tr>
<td>5.0 Evaluation of Solutions</td>
<td></td>
</tr>
<tr>
<td>5.1 Task Design</td>
<td>26</td>
</tr>
<tr>
<td>5.2 Experiment</td>
<td>27</td>
</tr>
<tr>
<td>5.2.1 Method</td>
<td>27</td>
</tr>
<tr>
<td>5.2.2 Table of Results</td>
<td>28</td>
</tr>
<tr>
<td>5.2.3 Results: Graphically displayed with comments</td>
<td>29</td>
</tr>
<tr>
<td>5.2.4 Summary of Results</td>
<td>34</td>
</tr>
<tr>
<td>5.2.5 Discussion of Results</td>
<td>34</td>
</tr>
<tr>
<td>5.2.6 Conclusions</td>
<td>35</td>
</tr>
<tr>
<td>5.2.7 Limitations of the Evaluation</td>
<td>36</td>
</tr>
<tr>
<td>6.0 Reflection</td>
<td></td>
</tr>
<tr>
<td>6.1 Possible Future Development of Solutions</td>
<td>38</td>
</tr>
<tr>
<td>6.1.1 Landmarks using Colour Assignment</td>
<td>38</td>
</tr>
<tr>
<td>6.1.2 Thermometer-style Depth Indicator</td>
<td>39</td>
</tr>
<tr>
<td>6.2 Was the Evaluation Criteria Achieved?</td>
<td>39</td>
</tr>
<tr>
<td>6.3 Reflection on Project Management</td>
<td>40</td>
</tr>
<tr>
<td>Bibliography</td>
<td></td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
</tr>
<tr>
<td>A. Lessons learnt from the project experience</td>
<td>44</td>
</tr>
<tr>
<td>B. Project Schedule</td>
<td>45</td>
</tr>
<tr>
<td>C. Paper details used to construct website</td>
<td>47</td>
</tr>
<tr>
<td>D. Tasks for website testing</td>
<td>49</td>
</tr>
<tr>
<td>E. Graphs displaying results from website experiments</td>
<td>50</td>
</tr>
</tbody>
</table>
## Table of Figures

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Figure Number and Description</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 Designing of Solutions to the Problem</td>
<td>Fig. 3.1 Depth indicator example with eight levels</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Fig. 3.2 Depth indicator example with five levels</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Fig. 3.3 Example of website using landmark navigation aid, Main Menu</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Fig. 3.4 Example of website using landmark navigation aid, Fish Menu</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Fig. 3.5 Example of website using landmark navigation aid, Red Herring Page</td>
<td>16</td>
</tr>
<tr>
<td>4.0 Implementation of Solutions</td>
<td>Fig. 4.1 Main menu of the control website</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.2 List of papers under the NIOSH section</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.3 Paper details and abstract</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.4 Main menu of the depth indicator website</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.5 List of papers under the NIOSH section of the depth indicator website</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.6 Paper details and abstract on the depth indicator website</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.7 Main menu of the website using the landmark navigation aid</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.8 List of papers under ‘Mental Rotation’ section on the landmark website</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.9 Paper details and abstract on the landmark website</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Fig. 4.10 Website structure with area covered by colour assignments shaded</td>
<td>25</td>
</tr>
<tr>
<td>5.0 Evaluation of Solutions</td>
<td>Fig. 5.1 Website Tests – Section One</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.2 Website Tests – Section Two</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.3 Table showing time (in seconds) taken for participants to complete tasks</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.4 Graph showing participants’ times for task 1.1</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.5 Graph showing participants’ times for task 1.2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.6 Graph showing participants’ times for task 1.3</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.7 Graph showing participants’ times for task 2.1</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.8 Graph showing participants’ times for task 2.2</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Fig. 5.9 Graph showing participants’ times for task 2.3</td>
<td>33</td>
</tr>
<tr>
<td>6.0 Reflection</td>
<td>Fig. 6.1 Landmark navigation aid shown with added topic selection list</td>
<td>38</td>
</tr>
</tbody>
</table>
1.0 Introduction to the Problem

1.1 Project Aim and Scope
My aim in this project was to develop a method for making websites more easily navigable. The starting point for the project was my supervisor, Roy Ruddle’s work into navigation in virtual environments (Ruddle, 2001). He investigated the effects that certain environmental factors had on people’s ability to navigate through virtual mazes and locate objects. Two of the factors he considered were a visually defined perimeter and the use of landmarks to mark the corners. The perimeter was made to look distinct from all the other walls in the maze by colouring it differently. This allowed the users to know when they had reached the edge of the maze and provided them with a sense of depth and orientation.

My intention was to apply these two environmental characteristics to website design in order to allow easier navigation. I evaluated my ideas by creating three websites, a control and two tests, and set participants tasks to find information contained within the Web site. The expectation was that easier navigation on these two test sites would manifest itself in reduced task performance times.

1.2 Minimum Requirements
1. Explore common problems encountered navigating the WWW.
2. Research any work already done in this field.
3. Suggest two possible solutions involving defined perimeters and landmarks.
4. Design three websites (one control and two test) to evaluate suggestions, using three volunteers per condition.

1.3 Evaluation Criteria
These are the criteria that will be used to evaluate the solutions produced during this project. Firstly, any solution produced must conform to the aim and scope of the project. More specifically solutions must attempt to improve Web navigation by defining the perimeters of websites or alternatively by making use of landmarks. This criterion is essential to ensure that the project remains within its stated aims.

Secondly, solutions should show an improvement in ease of navigation over an equivalent website with no navigational aids. This will be assessed by experiments where participants will perform information-seeking tasks. This requirement is straightforward. The main objective of the project is to improve navigation, so solutions that are produced must be evaluated in terms of how well they meet this objective.

Thirdly, the solutions presented should be reasonably easy to use and intuitive. Participants in the experiments should be able to use the navigation aids with minimal explanation and
tutoring. Usage of the navigation aids should not lead to cognitive overload. This criterion is needed to ensure that any solution produced is usable. The ultimate goal of this project is to describe and implement a navigation solution that could be used in all websites. If usability is poor though, no-one would bother to use it.

1.4 Initial Project Plan
The initial project plan set the following milestones, which combined would signal completion of the project; background reading, produce ideas, implement websites, test ideas and produce report.

Background Reading This activity commenced once project titles were allocated. Research had to be performed in order to gain an understanding of the problem and its context. It was necessary to review work already undertaken in this area and to read around the subject. This activity was useful when developing ideas.

Produce Ideas This was one of the hardest parts of the project. Using the knowledge gained from the background reading, ideas had to be formulated which would satisfy the evaluation criteria and be achievable in terms of the time constraints of the project, and in terms of my abilities.

Implement Websites There was a need to produce three websites. They would all have the same structure and content, but two would be enhanced with navigation aids. These would be used to evaluate the solutions.

Test Ideas Once the navigation aids had actually been implemented it was time to conduct experiments to evaluate whether they had achieved their aim of easing Web navigation.

Produce Report The production of the report activity took into account the need to submit deliverables before the Christmas and Easter vacations. The final report incorporated revised versions of these deliverables, but the main body of work was begun several weeks before the Easter vacation.

The project schedule outlining the planned completion dates of these activities is attached in Appendix B. The only change in this schedule from the one previously submitted as part of the mid-project report is the correction of the Easter vacation dates, which were originally mistakenly shown as being a week earlier.

Further details of the management of the project are provided in section 6.3 and Appendix A.
1.5 Introduction to the Problem of Navigation on the WWW

1.5.1 The Nature of the Web

According to the BBC News Website there were “over 36 million sites in cyberspace” in January 2002 (BBC News, 2002). These have been created by millions of independent contributors. The result is a mass of unscreened and unedited information that must be waded through in order to find useful, credible and well-presented information (Mayhew, 1998). One of the WWW’s greatest failing is the lack of quality control, both in content and presentation. No single organisation or body is in control of the World Wide Web and as such it is a chaotic environment in which to seek out specific information. “Hypermedia has the potential to greatly improve reading, writing, teaching, and learning, but it also has the potential to dramatically confuse and confound readers, writers, teachers, and learners” (Utting & Yankelovich, 1989).

The very nature of hypertext can often leave users feeling disorientated and confused. An early hypertext application was tested by Nielsen (1989) who reported that 56% of users claimed to have felt confused about where they were. It should be noted that this was within a single document, not a general statement about the World Wide Web, which is made up of millions of hyperlinked documents with no fixed structure. The ability of the Web to produce richly interconnected, complex, cross-referenced bodies of multimedia unfortunately also serves to produce complex disorganised tangles of haphazardly connected documents (Utting & Yankelovich, 1989).

When people use the Web it is usually in order to locate information or to find something useful or relevant to a task that they are attempting. Even when the Web is used for leisure purposes it is more likely that the user will be searching for something of interest to them personally, rather than just browsing aimlessly or following links at random. Users have been found to forage for information by following links from page to page as they pick up information scent. This scent takes the form of clues such as images or textual descriptions related to their search objective (Chi, 2000). The sheer size of the Web is such that any attempt to locate specific information must be based on an informed choice of route or search strategy to stand any realistic chance of success. Furnas (1997) notes that pure navigation (“wandering around and clicking things seen on the screen”) was abandoned in the early days of the Web in favour of using search engines, due to the near impossibility of finding anything specific.
Hammond & Allison (1989) describe common problems experienced by users of hypertext. Firstly users can become lost when navigating large, unfamiliar hypertext environments. The design of websites is often insufficient and doesn’t meet the needs of all levels of users. Secondly, it can be difficult for users to see the ‘big picture’ when they land on a website. They can misunderstand the relationships between different sections of a site. This is especially the case if they follow a link from a search engine and arrive at a point in the site where there is a lack of navigation information available. This is why website designers should prepare for users arriving at locations other than their special welcoming or start page, by including the title or logo of the site and providing a link back to the home page. A major problem that can be caused by the user failing to have an accurate overview of the website is that entire sections of the site go unnoticed. Thirdly, users may be unable to locate information that they know is present in the website’s content. This is because the structure of the site does not align with their preconceptions. Another cause could be that they do not understand the subject matter of the website well enough to choose the correct area of the website within which to search. Pirolli, Pitkow et al (1995) note that current Web browsers provide very little support to help users gain an overall assessment of the structure and content of websites.

1.5.2 Lack of Context Information
Confusion among those attempting to navigate the Web can easily arise since there is no perception of distance as hyperlinks ‘jump’ the user to another location (Nielsen, 1990). Whether this ‘jump’ carries them to a completely different location or one within the same site has a negligible effect on the loading time of the new page. The cause of this disorientation can be explained as the user lacking context information. Context information is defined as the explanation of users’ current situation in the Web environment (Park & Kim, 2000). Context information can provide the user with two specific forms of context, temporal and spatial. Spatial context shows the user where they can travel to from their current position, while temporal context involves showing the user previously encountered nodes that they visited recently. Whitaker (1998) describes a similar concept, situation awareness, which relates to the ability of the user to orient in space and time. The principal questions that can be answered by providing context information are, Where can I go from here? and How did I get here? (Park & Kim, 2000). These questions cannot always be answered satisfactorily by the browser so is up to the website designer to ensure that efforts are made to assist the user. A typical provision from Web browsers is a list of sites recently visited, known as the history. This provides the user with a form of temporal context.
1.5.3 Poor Design

Disorientation can occur easily when using the Web, as navigating a link may have unexpected outcomes. On some occasions navigating a series of links can transport a user around the same website or page, while on others, clicking on a link may transport them to a completely different site in both appearance and content. If the outcome of clicking on a link surprises the user it is usually a case of poor design.

Poorly designed websites can leave the user unsure as to the boundaries between sites. This is due to them having a poorly defined perimeter so users are able to leave the website without realising. Users may follow a link believing it is within the same site and instead be transported to a remote site. Some poorly designed websites make this too easy (Shubin, 1997). This is particularly common in e-commerce where a travel agent’s website may link to other sites for flight information or tourist guides. While having a range of information on hand can be useful it is sometimes hard for the user to find their way back to their previous position easily. This is a particular problem if the user had been in the middle of a transaction of some kind when they were distracted.

Links are also often included to product manufacturers, or advertisements that can coerce the user into getting sidetracked away from their main task. This kind of link is increasingly common on all types of websites, and is attractive since it provides a source of revenue as the host can receive payment each time someone clicks on the link or traverses the link and subsequently makes a purchase. The problem can be exacerbated by clever advertising where a banner advert displays buttons to fool the user into thinking they can perform some kind of task within the banner frame. Instead they are transported to the sponsors website. Although this performs a useful function for the advertiser, the result can be confusion for the user.

This chapter set out to introduce some of the problems associated with navigating the Web. Improved navigational support is needed (Jul, 1997) if users of the Web are to be able to efficiently locate specific items of interest. The next chapter will discuss the issue of Web navigation further and introduce some methods already attempted in order to improve navigability.
2.0 Background Research

2.1 Introduction
There have been various contributions to this area considering navigation in virtual environments using landmarks, and methods for improving the navigability of the WWW. In my project I will attempt to build upon the work of Ruddle (2001) and consider whether it is relevant when applied to web sites.

The starting point for the project was the work of Ruddle (2001) into navigation in virtual environments. The study used virtual 3D mazes to investigate the effects of these environmental characteristics upon spatial learning. Amongst others, factors considered were environmental characteristics such as visually defined perimeters and global landmarks (Evans, 1984). In one experiment Ruddle used a perimeter that was a different colour to the rest of the walls in the maze. This allowed the participant to be able to see when they had reached the edge of the maze, rather than a partitioning wall that they could navigate around. The study found that defining the perimeter of a maze increased the speed of spatial learning and reduced the time needed to perform searching tasks.

Another experiment was conducted that added landmarks to the corners of the maze. These landmarks were visible from every point in the maze but no significant advantages in spatial learning were observed. Possible explanations put forward for this unexpected result included that the spatial information provided by the perimeter was equal to that of the corner landmarks, or that the mazes used were simple enough for participants to navigate without relying on landmarks. A larger more complex maze would have increased the difficulty of executing a border-dominated strategy in order to find a target, and would therefore have placed more emphasis on navigating using landmarks.

2.2 Navigation using Landmarks
Navigation using landmarks involves using distinctive markers to find the route to the destination sought, and also to determine the position of the navigator along that route (Whitaker, 1998). Whitaker states that “unique visual clues are the critical element of this navigational aid.” Landmarks can be divided into two general types, global and local (Evans, 1984). Global or distant (Lynch, 1960) landmarks can be viewed from all parts of a certain environment and usually represent a faraway location or object. Examples include the Sun and the Pole Star in the natural world and distinctive buildings such as church towers or a skyscraper in the manmade environment. Local landmarks can only be seen from the immediate vicinity and inform the user of their current location. Examples of these include a street sign or distinctive tree.
Lynch (1960) discusses landmarks in the context of cities in his seminal work, The Image of the City. He classifies the contents of city images into five types of element; Paths, Edges, Districts, Nodes and Landmarks. He defines landmarks as a point-reference that the user does not enter in to. Observers can use landmarks as clues for the identity of their current location and they can be increasingly relied upon as a journey becomes more familiar.

Lynch observes that local landmarks are used to a greater extent by those people familiar with a certain environment. They are used in a sequential manner to give cues as to when a particular decision must be made. He found that it was people unfamiliar to an environment that tended to make use of global landmarks for information on orientation.

### 2.3 Landmarks in Virtual Environments

Vinson describes desirable features of landmarks in his paper, design guidelines for landmarks to support navigation in virtual environments (Vinson, 1999). He defines landmarks as distinctive environmental features functioning as reference points that ease navigation by indicating where certain actions (such as turn right) should be taken. He proceeds to say that landmarks support initial orientation and support the development of route knowledge. Vinson refers to the work of Lynch (1960) but uses the term landmark to mean all five of Lynch’s elements, as they can all provide orientation information to the navigator. Vinson states that landmarks should be distinctive in order to minimise confusion, but also suggests that each side of a landmark should be distinct to ensure the navigator can be sure of their orientation. This would solve the problem of having to view two landmarks simultaneously for orientation, but would increase the burden upon the navigator to remember perhaps four different faces or sides for each of the landmarks provided. Failure by the user to remember which visual images are associated with each landmark could result in the user becoming confused about their position. An alternative method of providing this orientation information is by placing two landmarks together. Vinson describes an example of a pine tree and a lamppost side by side. Depending on the observer’s orientation in relation to the landmarks they appear either with the tree on the left or right, or with one landmark obscuring or partially obscuring the other. Although this would involve using an extra landmark this would be of more use in a web site environment where generally a landmark (for instance a central node or distinctive feature) appears the same when you arrive at it, whichever direction you approach it from.

In the context of a website a landmark could be a unique icon that represents a function (Whitaker, 1998). It is important that such landmarks are designed to be unique, but are of a standardised format. For instance if a link to the homepage of a website appears on many
Background Research

pages it should be placed in a consistent position. Conforming to this approach will improve the navigability of the website for new and returning users.

2.4 Navigation on the Web
Furnas (1997) considers navigability in the context of the WWW in his paper Effective View Navigation. He uses ‘Logical Structure Graphs’ in order to illustrate how elements in an information structure are arranged. These graphs consist of points representing web pages (known as nodes) connected by lines representing the hyperlinks between them.

Furnas seeks out what factors are needed for efficient view traversibility (EVT), the ability to move between nodes (pages on the web) efficiently. He states that in order to attain EVT it is necessary to see at any one time only a small number of links compared to the overall size of the structure. This is to prevent the user from being faced with a daunting number of textual links that have to be sorted through and evaluated. Another factor needed for EVT, Furnas claims, is short paths between nodes. This means keeping the number of links that have to be followed to reach a certain node to a minimum. Organisational structures that follow these rules are balanced tree structures, and 3D structures such as cone trees and telephone directories. Telephone directories use columns and rows on each page (2D), then stack the pages on top of each other to form a 3D structure that is more EVT than a single ordered list would be. Even if efficient routes do exist between each node, it is still important that the user is able to find the path for the node they require. Furnas also describes rules to ensure that structures are navigable. For good navigation the information provided for a link must be well matched to the set of nodes it actually leads to. The information should not only describe the target node, but should describe the nodes that can be reached from the target as well. This is a challenging prospect but it would lead to good information residue throughout the structure. This leads to Furnas’ next rule, every node must have good information residue at every other node. This point is reiterated by the concept of information scent (Chi, 2000 & 2001).

Information residue is desirable since every node should be capable of being found from every other node, and therefore information residue should be present. In practice though, in a large structure, such as the WWW, this would be very hard to achieve without providing a number of very general categories and also a link to ‘other’ nodes. Furnas’ next rule is that outlink-info must be small. This prevents the information provided for a link becoming exhaustive.

It has been shown that navigation in structured manmade environments is not necessarily the same as navigation in natural environments (Whitaker, 1996). Differences found between the two environments include the cognitive processes required and the environmental cues used. This presents a problem for website designers since users may attempt to navigate a site in
different ways. Some may view a website as a highly structured series of documents. Others may view the same site as a frequently changing and unstructured site that had grown to its present format in an almost organic way. The way in which they approach navigation could be decided by a subjective view of the website. If it ‘looks’ structured one method of navigating could be used, while if it appears to be disorganised or poorly designed another method could be pursued.

2.5 Website Usability

Web site usability is discussed by Spool et al. (1999). Through carrying out information foraging experiments on nine different web sites Spool and his colleagues came to a number of surprising conclusions about web site design. Their study consisted of participants with varying experience of the web searching for answers to questions, where the answers could be found within the specific site they were told to search. The questions were of two types; simple questions that had definitive answers and comparison questions where two or more sources of information had to be found and compared.

In their study they found no evidence of participants forming a ‘mental map’ of a web site’s structure. Instead they tended to observe participants following an exploratory forward moving strategy before giving up if they were unable to find the target information. It was expected that users would form a map of how the information was organised and if they got lost they would return to a known point, or the last known point they had encountered. The study identified a possible use of landmarks where users were observed to return to the home page of a site to choose a link, even though that hyperlink had been available on the page they had just left. It was hypothesised that this was because the users’ perception was that they were less likely to get lost starting from a familiar point. This behaviour has also been observed during the testing of other software.

Sullivan et al (2000) extended the research of Spool et al (1999) focusing on Web navigation for children. They recommended that younger audiences would benefit from site wide navigation and orientation aids. Other findings included the discovery that decorative animations on websites tended to be viewed by the user as a distraction from the task being attempted.

2.6 Methods of Improving Navigability

Jakob Nielsen’s paper, The Art of Navigating Hypertext discusses a number of methods of improving the navigability of hypertext systems (Nielsen, 1990). The paper is based on a hypertext system presenting a report of events at the 1987 hypertext workshop. The system is small consisting of 95 screens but some of the principles can be applied to larger systems. He notes that landmarks exist within the system described, as nodes that are especially prominent
and are directly accessible from many of the other nodes. A specific example of a landmark within Nielsen’s system is the first page, which is accessible from all the main text pages, and also by repeatedly clicking on the back button. Nielsen also uses animation in an attempt to stop users becoming disorientated. If a user merely proceeded to the next screen, continuing through the same section, there was a page turn effect used. If the user clicked on a link to a remote area of the system however, a different effect was used. The user observed an iris-style in/out animation that was designed to provide a sense of movement through the system orthogonal to the simple left/right movement of the page turn. Another device to help users realise their position was the graphical design of the system. In some cases this was obvious for instance the first page encountered was designed to look like the front page of a book with the title and author displayed. There was a clear distinction between this page and the informative pages contained within. Nielsen also experimented with subtle background changes in order to represent different types of information in the system. During user testing however, users gave no indication of having noticed these subtle design differences and it was concluded that users do not associate screen colours with semantic importance. Nielsen hypothesised that this could be because screen colour is usually one of the few interface variables that users are allowed to alter. Overview diagrams were used by Nielsen to provide users with a sense of location. He used two levels, a coarse-grained diagram providing the user with a sense of orientation in the global information space and a fine-grained diagram for information on the local neighbourhood. This approach is not scalable however and for a large hypertext system more levels of overview diagrams would be needed and navigation among the diagrams themselves would become a problem. Hammond (1989) also showed evidence of a site map proving effective, but this too was on a reasonably small structure of 139 information pages. Mukherjea (1995) agrees that overview diagrams are a useful navigation tool in hypertext but warns that for real-world systems such diagrams would represent very complex structures.

A technique suitable for browsing large collections of documents is Scatter/Gather (Cutting, 1992). Scatter/Gather uses information structures where documents of a similar topic are clustered together with a summary describing the content of the cluster. The user ‘gathers’ information by selecting a cluster that seems appropriate to their search objective. At this point the documents contained in the selected cluster are ‘scattered’. This means they are broken into smaller clusters and these are displayed for the user to make a further selection. As the user selects clusters and sub-sections of these, each iteration produces clusters of a finer granularity until the user reaches the individual documents. Pirolli, Shank et al. (1996) found Scatter/Gather increased the development of users understanding of the contents of a
structure of documents, in addition to it being a feasible information retrieval technique in its own right.

This chapter discussed existing contributions to the field of navigation and the World Wide Web. In the next chapter a range of solutions to the problem of Web navigation using defined perimeters and landmarks are considered, and two are selected and described in detail.
3.0 Designing of Solutions to the Problem

3.1 Selection of Possible Solutions
A number of possible solutions were considered before two were finally selected. Some of those that were rejected are outlined below.

In order to provide information on the perimeter of a website site maps were considered. A site map could be designed for a website that would include clickable links and display a user’s position as they navigated around the site. The user would be able to see the overall limits, that is the size and the layout, of the website and know when they were approaching the perimeter. A navigation aid of this type could provide useful navigation information (Hammond 1989, Mukherjea 1995, & Nielsen 1990) and many existing websites employ a site map of some sort. One problem with site maps however is that for a large website, that may include thousands of web pages the site map itself can become incredibly complicated and difficult to navigate. While they can prove effective on small to medium sites they are not scalable.

A dynamic site map could be the solution to some of these problems. If a site map could incorporate a fish-eye effect so that only the area being focused on by the user was shown in detail, this could reduce the amount of information displayed to a user concurrently and so reduce confusion. The rest of the website would be represented by significant nodes, while lesser nodes would be hidden until the area they existed in came under focus from the user. So if a user were viewing a certain page of the website, the site map would display all links to pages available from that location, but web pages further away would only be displayed if they were significant. Significant pages would include menu pages and title or introduction pages for different sections of the website.

Another idea was to provide the user with an abstract site map that hides the details of the structure of the website from the user and instead presents it as a simple understandable layout. This would not seek to provide accurate high detail structural information, but instead be an aid to represent the website’s general structure, organisation and perimeter, and the user’s position within it. The aim of this idea was to provide the user with easy to understand contextual information without confusing them. By it’s very nature though abstraction would rid the map of some of its detail. This could present a problem if the user is unable to see the information they require. This idea was not pursued, as it was uncertain whether abstracting a complicated site map would aid or impede navigation.
The two solutions that were selected are shown and explained in detail below.

3.2 Description of Chosen Solutions

The two solutions chosen were selected because they appeared to be potentially beneficial to the problem of web navigation. In accordance with the evaluation criteria specified in section 1.3 they also adhered to the scope and focus of this project. One aid concentrates on the perimeter of the website (the depth indicator) and the other is primarily concerned with landmarks but also includes some definition of topic boundaries.

3.2.1 Thermometer-style depth indicator

This navigation aid was designed to give information on the perimeter of the web site. This was based on Ruddle’s (2001) experiments involving perimeters in 3D virtual environments. It did this by showing the overall limits of the web site and the limits of the current route. The depth indicator displays to the user the number of levels the web site consists of. In a hierarchical structure the concept of levels is a simple one. Starting at the root node and proceeding down to a leaf node, the maximum number of nodes the user can encounter is the overall depth of the site. The depth indicator shows the number of levels in a site by breaking the ‘thermometer’ into sections with each section representing a level. An additional section was added to the thermometer and coloured red to represent the end of the route. All other sections were coloured green to show that they were available on the current route. A black dot on the thermometer indicated the user’s current position. Navigation to previously visited nodes was possible either by clicking on the thermometer section representing that node or by clicking on a text label adjacent to that section.

This depth indicator shows a structure containing eight levels. The red section shows that the structure has ended. The black dot shows that the user is currently at the first level.

The key to the right accompanies the depth indicator to provide the user with information on how to use the navigation aid.

In a hierarchical structure that isn’t perfectly balanced, branches of the tree will be of varying lengths. This is reflected in the depth indicator by the lower levels of the thermometer turning red when a user navigates onto a shorter branch.
For example, using a structure with the same number of levels as the depth indicator shown above, a user may be able to navigate onto a branch that was only five levels deep. This would be represented by the three lower sections turning red to show that they were no longer accessible on the current route (Fig 3.2). The depth indicator now shows the user that on the current route there are five levels accessible. In this example the user is currently on the third level. It also informs the user that additional levels are available on the web site by pursuing a different route down the hierarchy.

Fig 3.2 Depth indicator example with five levels
3.2.2 Landmarks using Colour Assignment

The idea behind this navigation aid was to provide the user with the equivalent of a landmark. In a town a landmark could be a distinctive building which is associated with a specific area of the town (Lynch, 1960). By heading towards that building an individual knows that they are heading towards that area, and when they are next to the building they know they are in that area. To attempt to recreate this in the context of a web site, different colours were assigned to different subject areas. The assignments were shown in a key, which was displayed in a separate frame down the side of the screen so that the user could refer to them at all times. Next to the hyperlinks in the main part of the site are bars, which display the colours of each subject area that can be reached by following that link. Where bars contain white this shows that there are other subject areas besides ones assigned a colour also accessible from that link. Once the user reaches the subject area coloured horizontal lines appeared at the top of the screen framing the page title. These lines are coloured to match the subject area’s assigned colour. This visual clue to the user’s position remains as they navigate around that area, then disappears as they ascend back up the hierarchy leaving the area.

In this example the website has three categories, birds, land animals and fish. The frame on the left displays colours that have been assigned to different animals, for example dark blue for eagle and yellow for giraffe. The coloured bars on the right of the category names inform the user in which category these animals can be found. This is a trivial example, but if the subject of the website was one with which the user was unfamiliar then this could be a valuable navigation aid.

![Fig 3.3 Example of website using landmark navigation aid, Main Menu](Image)
In this example the user is looking for the page on Red Herrings. By following the links with the red bar next to them, the user locates the page and is informed they are in the correct location by the red lines framing the page title (Fig 3.5).

<table>
<thead>
<tr>
<th>Colour Assignments</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eagle</td>
<td></td>
</tr>
<tr>
<td>Seagull</td>
<td></td>
</tr>
<tr>
<td>Robin</td>
<td></td>
</tr>
<tr>
<td>Dog</td>
<td></td>
</tr>
<tr>
<td>Tiger</td>
<td></td>
</tr>
<tr>
<td>Parrot</td>
<td></td>
</tr>
<tr>
<td>Shark</td>
<td></td>
</tr>
<tr>
<td>Red Herring</td>
<td></td>
</tr>
<tr>
<td>Tuna</td>
<td></td>
</tr>
</tbody>
</table>

**Fig 3.4 Example of website using landmark navigation aid, Fish Menu**

<table>
<thead>
<tr>
<th>Colour Assignments</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eagle</td>
<td></td>
</tr>
<tr>
<td>Seagull</td>
<td></td>
</tr>
<tr>
<td>Robin</td>
<td></td>
</tr>
<tr>
<td>Dog</td>
<td></td>
</tr>
<tr>
<td>Tiger</td>
<td></td>
</tr>
<tr>
<td>Parrot</td>
<td></td>
</tr>
<tr>
<td>Shark</td>
<td></td>
</tr>
<tr>
<td>Red Herring</td>
<td></td>
</tr>
<tr>
<td>Tuna</td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig 3.5 Example of website using landmark navigation aid, Red Herring Page**
4.0 Implementation of Solutions

4.1 Designing the control condition
In order to properly evaluate the solutions a website was needed. This would be used as the control condition and then be enhanced with the two navigation aids. At the suggestion of my supervisor Dr. Roy Ruddle I collaborated with another student, Andrew Stubbs to produce the site. Andrew was working on a similar project also under the supervision of Dr. Ruddle and he too was in need of a web site to use as a control condition. Our supervisor had maintained a file consisting of details of scientific papers he had read and we decided to construct a web site using this information. We decided upon a hierarchically structured web site where the root of the tree structure was the ‘point of entry’. The first point of branching was a menu of main categories; the structure then branched further into subcategories, with the leaf nodes containing the paper details. For each paper there was a page containing the title, author/s, year published and the abstract. In some cases we were unable to acquire a paper’s abstract, when this occurred the abstract was replaced with a note stating it was unavailable. We made the decision that each paper would be placed under just one category. In all there were 130 papers. This provided a structure complex enough for a user to become disorientated in. It was hoped that this would lead to an improvement in task completion times once navigation aids were introduced. The complete structure is shown in section 4.1.3.

4.1.1 Implementing the control condition - Division of Work
Andrew and I worked together on designing the structure of the web site. Andrew then produced the menus for the site and located abstracts for the papers. I wrote a C++ program that generated the leaf nodes containing the paper details. The program also placed links to these paper details in the appropriate menus of the website’s structure. Once the control condition was completed our collaboration ended, and we worked on our individual projects once again.

4.1.2 Details of the HTML-builder program
The program was developed to automatically generate the HTML for the leaf nodes of the test websites. Each leaf node was a .htm file that contained the details of a paper i.e. the title, authors, year published and abstract. By producing the HTML with this method, changes in design could be implemented much more easily than if each file had to be altered individually.

The program worked by reading in all the paper details from a data file (which was specified as a command line argument). This file also contained the category each paper had been classed under. Each paper’s details were then outputted to a new file embedded in HTML.
The program then opened the HTML file where the paper would be linked to and added a new link for each paper. A subset of the data file containing the paper details is attached in Appendix C.

Pseudo-code for the program:

Check there is a command line argument, output error message if there isn’t
Open the data file, output error message if failure occurs

Output “Enter number of papers”
*User inputs the number of papers in the data file*

For loop begins with iteration for each paper in the data file
   HTM file is created and named paper*.htm where * is the iteration number
   Paper title read in
   Paper authors read in
   Read in the year paper was published
   Read in category name
   Open category’s .htm file
   Append link to category’s web page
   Close category’s .htm file
   Read in abstract
   Output title, authors, year published and abstract with accompanying HTML to paper*.htm
   Close paper*.htm
   End of Loop – repeat for next paper

Close data file
4.1.3 Structure of the Website

At this point in the structure there was a list of papers. Each paper title was a link to a web page containing the paper’s details and abstract.
4.1.4 Screenshots from the Control Condition Website

**Fig 4.1 Main menu of the control condition**

**Main Categories**

The collection of research papers has been split into four major categories. Please click on the link below to select the appropriate category:

1. **Navigation**
2. **Virtual Environments**
3. **Bio & Ergonomics**
4. **Objects and Manipulation**

Click [here](#) to return to previous page.

**Fig 4.2 List of papers under the NIOSH section**

**NIOSH Lifting Equation**

Please click on a link below to view details of that paper.

Click [here](#) to return to previous page.


*Waters, B., & Kemeny.* Accuracy of measurements for the revised NIOSH lifting equation. 1999

*Potestl, P., Anderson, R., Bobek, M., & Goldin, P.* Understanding and evaluating manual handling forces. NIOSH research studies. No data available.


**Fig 4.3 Paper details and abstract**

**Title:** Accuracy of measurements for the revised NIOSH lifting equation

**Author(s):** Waters, B., Kemeny

**Published:** 1999

**Abstract:** Twenty-seven non-ergonomists who participated in a one-day training session on the use of the NIOSH lifting equation (NLT) were subsequently tested on a simulated lifting task eight weeks later to determine their accuracy in measuring the variables. Analysis of the results indicates that (1) inter-observer variability was small, especially for the most important factor (i.e., horizontal distance), (2) individuals can be trained to make measurements with sufficient accuracy to provide consistent recommended weight limits and lifting index values, and (3) measurement of the coupling and asymmetric variables were the least accurate.

Published by Elsevier Science Ltd.
4.2 Thermometer-style Depth Indicator
The depth indicator navigation aid was implemented by altering a standard GIF image that had been created in Paint Shop Pro. There were seventeen thermometer images used in total to cover all permutations of different levels and locations needed. The images were inserted into the standard website that had been created for the control condition so that they appeared between the page title and the choice of links for that page. An image map was created to fit the thermometer and this was tailored to allow backward navigation from a web page to any of the previously visited pages higher on that route. When the mouse pointer was moved over part of the thermometer that was a link, the destination was displayed. In addition to this there were text labels besides each section of the thermometer that had previously been visited to show the user’s route to their current position. These text labels were also links. Next to each thermometer was a key to remind the user of the meanings of the red and green sections, and also of the black dot. The thermometer used for the website was made up of eight levels.

Shown below are some screenshots of the thermometer-style depth indicator incorporated into the website.

![Fig 4.4 Main menu of the depth indicator website](image-url)
Implementation of Solutions

Fig 4.5 List of papers under the NIOSH section of the depth indicator website

Fig 4.6 Paper details and abstract on the depth indicator website
4.3 Landmarks using Colour Assignment

In a similar fashion to the depth indicator this navigation aid was also added onto the control condition website. A frame was created that occupied the left of the screen. This was used to display the key which informed the user which colour had been assigned to which topic. The colours chosen were all Internet safe, meaning that they would be displayed correctly by all browsers. Coloured bars were placed alongside the menu categories using HTML table tags to ensure the alignment was neat. These were GIF images created in Paint Shop Pro. The division of the coloured bars into the different colours approximately represented the proportion of the category that was concerned with the topic assigned to that colour. The white space in the coloured bars represented other material within the website’s structure that was not assigned a colour. Generally a topic was assigned a colour if it was a reasonably large collection of papers, and it was not clearly obvious from the menu which category it fell under. Of the twenty-three sub-categories that papers eventually fell under, seventeen were either allocated a colour outright, or formed part of a larger topic that had been allocated a topic, such as ‘Lifting and NIOSH’. The others were either easy to find or were small categories. Fig. 4.10 shows the structure of the website with the area covered by colour assignments shaded.
Implementation of Solutions

Key to Colour Schemes

- Aircraft and HUD
- Spatial knowledge and Orientation
- Visualization
- Interaction Devices
- Teleoperation
- Immersive VE
- Collaborative VE
- Desktop VE
- Mental Rotation
- Lifing and NUGSH

Mental Rotation

Please click on a link below to view details of that paper.

Click here to return to previous page

Shapard + Menner, Mental Rotation of Three-dimensional Objects (21), 1971
Shapard + Todd, Perceptual Rotation of Three-dimensional Objects, 1976
Rutheiff + Miller, Can mental rotation begin before perception finishes?, 1995
Horton + Pasqu, Scene-based and viewer-centered representations for comparing shapes, 1988
Perrett, Oram + Ashbridge, Evidence accumulation in cell populations responsive to faces: an account of generalization of recognition without mental transformations, 1990
Wester, Good + Bentin, Motor processes in mental rotation, 1998

Fig. 4.8 List of papers under ‘Mental Rotation’ section on the landmark website

Title: Can mental rotation begin before perception finishes?

Author(s): Rutheiff + Miller
Year Published: 1995

Abstract: We conducted an experiment to determine if mental rotation can begin before perception finishes, as allowed by continuous flow models but not discrete stage models of information processing. The results of Experiments 1-3 showed that the effect of shape discrimimability in RT was underdetermined with the effect of stimulus orientation, suggesting that mental rotation began before shape discrimination had finished and that the two processes overlapped in time. The results of Experiments 4-6 indicated that mental rotation can overlap with color discriminations as well. In both sets of experiments, however, the amount of underdetermination tended to be much less than predicted by models allowing interference-free overlap. This suggests that mental rotation can cohere with percepctual analysis, contrary to fully discrete models, but that little rotation is carried out during this overlap due to interference between simultaneous discrimination and rotation processes.

Fig. 4.9 Paper details and abstract on the landmark website
Fig 4.10 Website structure with area covered by colour assignments shaded
5.0 Evaluation of Solutions
To evaluate the two navigation aids three sets of tests were conducted. The first on a simple website devoid of any navigation aids called the control condition, the other two sets were conducted on the two test conditions. The structure of the three websites was identical. This approach was used to determine whether any significant changes in task performance times occurred when participants had access to navigation aids. As well as comparing the performance of the navigation aids to that of the control condition, it was also an objective to observe how the two navigation aids performed in relation to each other.

5.1 Task Design
In order to evaluate the two test conditions it was necessary to design equivalent tasks that could be performed on the websites to decide whether incorporating the navigation aids made it easier or harder to perform the tasks.

The first section of the tasks (fig 5.1) was designed to test how quickly a paper could be located on the website given the title and author. Participants were required to find the paper’s location and then click on the link to display the paper’s abstract. At this point the stopwatch was stopped.

<table>
<thead>
<tr>
<th>Section One</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Locate the following paper, Roscoe, Airborne displays for flight and navigation</td>
</tr>
<tr>
<td>2. Locate the following paper, Editorial, Back injury at work: a new beginning for prevention</td>
</tr>
<tr>
<td>3. Locate the following paper, Hindmarsh, Fraser, Heath, Benford + Greenhaigh, Object focussed interaction in collaborative virtual environments</td>
</tr>
</tbody>
</table>

Fig. 5.1. Website Tests – Section One

The second section of the tasks (fig 5.2) tested the participants understanding of the structure of the website. They involved the participant making a decision on the bounds of a question and judging when they had gathered all the information required for them to be able to answer it.

<table>
<thead>
<tr>
<th>Section Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How many papers have Slater and Uosh collaborated on in the field of Presence in Immersive Virtual Environments?</td>
</tr>
<tr>
<td>2. How many of the papers in the Mental Rotation section have abstracts available?</td>
</tr>
<tr>
<td>3. How many papers are there on the theme of Visualisation? (Hint: there may be more than one group)</td>
</tr>
</tbody>
</table>

Fig.5.2. Website Tests – Section Two
In the first question of section two there are three papers in the Presence subcategory of the Immersive Virtual Environments category that include Slater and Uosh among their authors. There is however another paper in a separate subcategory of Immersive Virtual Environments written by Slater and Uosh. This should not be counted since it is not in the Presence section but may cause confusion if participants do not restrict their search accordingly. In the third question participants are asked how many papers there are on the theme of Visualisation. There are two visualisation sections on the website, one under the Human Interaction section and one under the Technology section. The task required the participant to locate both of these and count the papers. Implicitly they also had to decide whether there were likely to be any other visualisation sections to locate.

5.2 Experiment

5.2.1 Method
The participants in the experiments were all students from the School of Computing at the University of Leeds and were second or third years. They were aged between 20 and 23 years with a mean age of 20.8 years. Eight were male while one was female. All participants had extensive experience of navigating the WWW and were familiar with hypertext interfaces. Participants were recruited from the School’s laboratories and gave up their time freely.

Participants were briefed on the nature of the website; that it was hierarchical with details of scientific papers at the lowest level. In the case of the two navigation aids their purpose was explained to participants along with how to use them. It was explained that the tasks would be timed for comparison and that the clock would be stopped either when the correct paper details were displayed on screen or when an answer was given to a question. Each task was initiated from the ‘Main Categories’ page of the website. The clock was started as the participant was directed to proceed and stopped when either the correct paper details were displayed on screen, or the correct answer to the question was given. Alternatively the clock was also stopped if the participant chose to abandon a task, or gave an incorrect answer. Three participants were used for each condition, one control and two tests. No experiment took longer than ten minutes for the participant to complete all the tasks.
### 5.2.2 Table of Results

Below are the raw results from the experiments.

<table>
<thead>
<tr>
<th>Test Group</th>
<th>Participant</th>
<th>Task Number</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>2.1</th>
<th>2.2</th>
<th>2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
<td></td>
<td>23</td>
<td>31</td>
<td>111</td>
<td>34</td>
<td>37</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>30</td>
<td>57</td>
<td>36</td>
<td>92</td>
<td>50</td>
<td>43 X</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>31</td>
<td>78</td>
<td>50</td>
<td>70</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Depth</td>
<td>1</td>
<td></td>
<td>8</td>
<td>Gave up after 135</td>
<td>43</td>
<td>43</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>10</td>
<td>Gave up after 180</td>
<td>16</td>
<td>16</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>8</td>
<td>90</td>
<td>16</td>
<td>15</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Landmark</td>
<td>1</td>
<td></td>
<td>7</td>
<td>113</td>
<td>93</td>
<td>60</td>
<td>23</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>11</td>
<td>20</td>
<td>23</td>
<td>33 X</td>
<td>29</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>41</td>
<td>Gave up after 168</td>
<td>35</td>
<td>78 X</td>
<td>26</td>
<td>55</td>
</tr>
</tbody>
</table>

Where X follows the time an incorrect answer was given.

*Fig 5.3 Table showing time (in seconds) taken for participants to complete tasks*
5.2.3 Results: Graphically displayed with comments

The following graphs illustrate the performances of each test group compared on a task by task basis. Along the x-axis are the participants of each test group followed by the mean time for that group’s performance on that task. Each test group is represented by prefixes as follows:

- c = control group
- l = landmark group
- d = depth indicator group

Times are shown in seconds.

Section One

The first section of tasks was comprised of simple searches to find a specific paper.

Task 1.1

*Locate the following paper,*

*Roscoe, Airborne displays for flight and navigation*

![Times for Task 1.1](image)

*Fig 5.4 Graph showing participants’ times for task 1.1*

Most participants were able to find this paper quickly. The landmark website came out on top with a mean time of 8.7 seconds compared to those of the depth indicator website and the control condition, which had means time of 19.7 and 28 seconds respectively.
Task 1.2

Locate the following paper,
   Editorial, Back injury at work: a new beginning for prevention

Fig 5.5 Graph showing participants’ times for task 1.2

In most tasks the navigation aids showed an improvement in task completion times over those of the control condition. The only task that showed the navigation aids to be significantly worse than the control condition was task 1.2, where half of the participants using navigation aids actually gave up on the task before completion. The question posed focused on one of the more ambiguous sections of the website’s hierarchy and all but one of the participants began to search under the wrong category. This task is discussed further in section 5.2.5. The participant who began searching in the correct category was using the website with the depth indicator and found the paper quickly with a time of 20 seconds.

The mean time for the control condition was 55.3 while the mean time for the depth indicator was 66.5. Since only one participant of those testing the landmark website managed to complete the task there was not a mean calculated for this condition.
Task 1.3

Locate the following paper,
Hindmarsh, Fraser, Heath, Benford + Greenhaigh, Object focussed interaction in collaborative virtual environments

![Graph showing participants' times for task 1.3](image)

As the graph shows, times taken for this task varied widely even between participants using the same websites. Taking the mean times for each condition though we can see that the control condition is outperformed by both of the navigation aids. The mean time for the control condition is 65.7 seconds, while the mean times for the landmark website and the depth indicator website are 25 seconds and 50.3 seconds respectively.
Section Two
The tasks in the second section were slightly more complicated and required the participant to give a numerical answer to the question posed. Four of the answers given during the experiments were incorrect.

Task 2.1
*How many papers have Slater and Uosh collaborated on in the field of Presence in Immersive Virtual Environments?*

Two people, both coincidentally in the depth indicator group answered this question incorrectly. They located a paper upon which Slater and Uosh had collaborated that resided in a section of Immersive Virtual Environments other than presence. This led them to give the answer four, when in fact the correct answer was three. No other participants seemed to encounter any problems, although some of the participants using the control condition were slow to find the appropriate section.

The mean times for the test conditions were 65.3 seconds for the control condition, and 24.7 for the landmark website. Only one correct answer was given for the depth indicator website so no mean was produced. If the answers had been correct however then the mean time would have been lower than that of the control condition at 57 seconds.
Task 2.2

*How many of the papers in the Mental Rotation section have abstracts available?*

![Fig 5.8 Graph showing participants’ times for task 2.2](image)

This question caused no problems for the participants with most answering correctly within 30 seconds. The mean times were 35.7 seconds for the control condition, and 28.3 seconds and 26 seconds for the landmark website and the depth indicator website respectively.

Task 2.3

*How many papers are there on the theme of Visualisation? (Hint: there may be more than one group)*

![Fig 5.9 Graph showing participants’ times for task 2.3](image)
In this task the depth indicator website failed to outperform the control website. A participant using the control condition gave an incorrect answer however. The task required the user to find two separate sections on the theme of visualisation. One was under Virtual Environments, Human Interaction Issues and the other was under Virtual Environments, Technological Issues. The participant who gave the wrong answer only found one of the sections before giving an answer. The mean times for this task were 44 seconds for the control condition, and 31 seconds and 56.7 seconds for the landmark website and the depth indicator website respectively.

5.2.4 Summary of Results
The results for task 1.2 were ignored due to problems with the question being experienced by participants. This is discussed further in the next section, 5.2.5. In the five remaining tasks the website enhanced with the landmark aid achieved the best mean times in four tasks, and performed better than the control website in all tasks. The website with the depth indicator performed less well but beat the control website three times and achieved the best mean time once. In order to compare the graphs from the experiments more easily they are reprinted in Appendix E.

5.2.5 Discussion of Results
A problem was encountered with question two of the first section of the tasks (Tasks for website testing, Appendix D). All but one of the participants began looking for the paper on back injuries at work under the ‘Bio and Ergonomics’ category rather than the ‘Objects and Manipulation’ category. This was an understandable mistake resulting from some ambiguity in the naming and classification of categories. The problem still occurred when the landmark navigation aid was used, although this showed that papers on ‘Lifting’ could be found in the ‘Object and Manipulation’ category.

An interesting result of this problem was that participants could be observed reacting to an unexpected result. Some participants returned to the ‘Main Categories’ page and re-evaluated their options given that ‘Bio and Ergonomics’ had been found to be unsuccessful. These participants tended to quickly locate the paper. Other participants immediately pursued an exhaustive search strategy, looking down completely unrelated category routes, but methodically investigating each until they found the paper. Three participants actually gave up on the task entirely. One of these had unknowingly found the correct page where the link to the paper had been displayed but had failed to notice it.
In task 2.1 the depth indicator was not given a mean time. This was because two of the three answers given were incorrect. The one correct answer was given in a time less than that of the control group’s mean time however. Had a mean time been calculated from the three times shown on the graph (Fig. 5.7), this would also be less than the control group’s mean time.

5.2.6 Conclusions

The Landmark aid appears to be a good solution.

The results reveal that the website enhanced with the landmark navigation aid showed a significant improvement in performance over the control condition. Disregarding task 1.2 (as previously discussed in sections 5.2.4 and 5.2.5) the times taken for the landmark website participants to complete the navigation tasks were shorter than those of the control condition in all tasks. The landmark aid also consistently outperformed the other navigation aid being evaluated. The only task where the depth indicator aid performed better than the landmark aid, the difference between the two mean times was marginal (2.3 seconds).

From the experiments performed during this project the indication is that the landmark navigation aid could be used in a Web environment to improve the ease with which users are able to navigate around and locate areas of interest within that environment.

The Depth indicator aid requires further testing.

The thermometer-style depth indicator had mixed results. In three of the five tasks it performed better than the control condition, in one it’s performance was worse, and in the remaining task the times were better than the control condition, but the answers given were incorrect.

It was hoped that the depth indicator would provide a means of defining the perimeter of the website by showing the depth of the website as a whole and the individual branches within it. It is difficult to tell whether the navigation aid succeeded in communicating the perimeter of the website to the user, but generally it showed an improvement over the control website. This was encouraging but it is unclear whether this was the result of structural information being gained by the user, or the additional links embedded in the aid easing movement around the website. The depth indicator could potentially be a useful aid to navigation but further testing is needed to ascertain whether or not this is the case.

Limitations of the evaluation are discussed below (section 5.2.7) and possible developments of the solutions are suggested in the next chapter, 6.0 Reflection.
5.2.7 Limitations of the Evaluation

*Hierarchy vs. web*

The structure used in the evaluation in this report was a hierarchy. This is a very common structure on the Web, since it is logical and quick to learn. Hierarchical structures are often found in online shops where products are separated into categories. Many websites are more complex than this however and if their structure were to be represented by a diagram it would resemble a web rather than a tree-like hierarchy. Even website structures that are primarily hierarchical can contain many hyperlinks that cross between branches. It would be a valuable exercise to evaluate the navigation aids described in this report on a web-like structure in order to test them in a more volatile environment. For this to be achieved the depth indicator aid would need to be modified to dynamically display the user’s path to the current node. This would be necessary if for example, a paper was reachable from two different categories.

*Scalability of Landmark solution – distinct colours*

Despite the success of the Landmarks using Colour Assignment navigation aid there is one significant problem. In a structure with a wide variety of topic areas, there may well be more topic areas that the designer wishes to emphasise than visually distinct colours available. This means that the solution as it appears in the evaluation tests in this report is not scalable. Thousands of colours could be chosen to represent thousands of topic areas, but this would lead to user confusion as varying shades of the same colour would be difficult to distinguish.

*Number of participants – reliable results?*

There were a total of nine participants involved in testing the navigation aids. Three were in the control group testing the website devoid of navigation aids. Three tested the landmark navigation aid and three tested the depth indicator aid. Nine participants are not enough to be able to draw firm conclusions although they can give an initial indication of the usefulness of these aids. Further testing would be needed in order to corroborate the conclusions drawn in this report. Ten participants for each condition would be a logical next step, although the results would become more reliable if even more participants were involved. The participants I chose were all selected from the School of Computing since they all had extensive experience of Web navigation. They also had the benefit of a better than average level of understanding of the terminology involved in the example website used. That is not to say however that the topic was a familiar one.

*Spread of navigation talent across tasks.*

Although all participants had extensive experience of Web navigation there was a notable difference in the strategies used. Some participants showed a high level of observation. When
they found themselves making a mistake and following the wrong link, they recalled what had been down that route in later tasks. This meant that they were able to perform better as the experiment went on since they were actually beginning to learn the system. Other users showed no sign of this and visited the same locations more than once in a single search. Also they had trouble locating a topic when they had passed it several times in a previous task.

Getting an even spread of navigation talent across tasks is important for the evaluation. With only nine participants an exceptionally good or bad navigator can disrupt the results. This would become less of a problem if the experiment were to be repeated with more participants, since a single participant would become statistically less significant.

*Commitment of participants – could they really be bothered?*

One participant was tested during the afternoon and after the experiment admitted that he had been in the library all morning looking for material for his own project and that this was the last thing he felt like doing. Although the experiments typically lasted only 5-10 minutes they were conducted at a time where many of the participants were busy with other work. The participants were all colleagues from my department and they gave up their time freely to assist with this project. However, if the experiments were to be repeated I would introduce a small cash prize for the best performance in the experiment in order to secure participants full concentration. Despite the participant’s comment above there is no reason to believe that the participants were in any way uncommitted to the task they had been asked to perform.
6.0 Reflection

6.1 Possible Future Development of Solutions

6.1.1 Landmark using Colour Assignment

As discussed in the previous section (5.2.7), the landmark aid suffers from scalability problems. The major problem being that there may be more topics than distinct colours. A way of reducing the number of topics and perhaps increasing the effectiveness of the aid would be to allow the user to decide which topics are allocated colours. There could be several default topics that are assigned colours and a drop-down menu where other topics can be selected. Upon selecting a topic it would appear in the colour assignment key on the left of the screen and the assigned colour would appear in the appropriate bars.

It could also be useful if users could select what colour should represent what topic. In some situations a certain colour may have a real life association with a topic and selecting another colour in its place would cause confusion. Allowing the user to select which colours are used would also overcome the problems that colour-blind users may experience. Previously the aid was not configurable and visually impaired users who could not distinguish certain colours would have been unable to use the aid effectively. By being able to choose which colours are assigned to which topics, colours that can not be distinguished could be replaced with more appropriate choices of colours.

The landmark navigation aid uses a colour key down the left-hand side of the screen to display to the user which colours are assigned to which topics. It was tempting to make each topic name a link in order to speed up navigation. This was not done since the project sought to test the effectiveness of landmarks and this would have just been a list of links. In a real life application though it could be useful to use the colour key as a navigation bar as well. This would mean that users could reach specific information quicker, but use the landmark aid for information where the exact location is unknown and browsing is necessary.
6.1.2 Thermometer-style Depth Indicator
In the evaluation it was shown that for the majority of the navigation tasks conducted, the website enhanced with the depth indicator performed better than the control condition. The results were mixed however and more testing was recommended. A possibility is that the depth indicator could be more effective if it was used in tandem with another navigation aid. For example, the integration of the two navigation aids described in this report may provide better task performances than either of them could separately. Alternatively, if another navigation aid could be found or developed that provided a similar style of context information to the depth indicator then the two could either be combined or used side by side. Ideally the other navigation aid would provide information on the breadth of the site in order to complete the user’s knowledge of the website’s perimeter.

6.2 Was the Evaluation Criteria Achieved?
The two navigation aids were developed with the aim and scope of the project in mind. The depth indicator was concerned with defining the perimeter of the website, while the landmark aid concentrated on landmarks and some definition of area perimeters within the site. This clearly falls within the scope of the project as defined in the introduction (section 1.0).

The results from the evaluation chapter (section 5.2.4) show that both solutions were successful in improving navigation. Improving navigation was assessed by tasks (shown in Appendix D) being performed on the two test websites and a control condition website devoid of any navigation aids. If the websites enhanced with navigation aids were easier to navigate it was expected that participants would perform the tasks in less time than the control condition. This turned out to be the case, with one navigation aid (the landmark aid) demonstrating a significant reduction in times and the other showing a modest improvement on the control condition.

The two navigation aids were designed to be relatively simple to understand and use. The purpose of the landmark aid is fairly obvious but users have to begin by relating the coloured bars next to the links with their respective link. They also have to associate the colours in the assignment key with the coloured bars. The depth indicator aid becomes clear to users once they navigate down the hierarchy of the website and see the aid respond to the movement. The links on the depth indicator are intuitive and it doesn’t matter whether the user prefers to click on a section’s text label or the actual thermometer section itself. For most users it is likely that some prompting would be beneficial either with helpful guidance from accompanying text or via a short tutorial.
6.3 Reflection on Project Management

The initial project schedule (shown in Appendix B) was not adhered to rigidly but formed a rough view of how the work was approached. The websites took longer to produce than was anticipated at the outset. This was due to problems classifying papers into categories and deciding upon the structure the website would take. I was collaborating with Andrew Stubbs (see section 4.1.1) at this point but several iterations were needed until we were satisfied with the structure. The C++ program that was produced to generate the leaf nodes of the website’s structure was also a challenge. Difficulties with the coding of this program led to more time being spent on it than would have been ideal. Once the websites were complete and the navigation aids had been implemented, the experiments were due to be conducted. The experiments went well in that they progressed quickly and without major problems. One of the tasks I set was reliant on a section of the website structure that was ambiguous. This is discussed in more detail in section 5.2.5. The actual process of the experiments was completed over two days, in my project schedule I had allocated two weeks for testing. This meant that the delay at the implementation stage was compensated for and the project continued on schedule once more. As expected the majority of the writing up of the final report was completed towards the end of the project, commencing a couple of weeks before the Easter vacation. There is more reflection on the project process included in Appendix A – Lessons learnt from the project experience.
Bibliography

BBC News Website (2002) – Science section
http://news.bbc.co.uk/hi/english/sci/tech/newsid_1738000/1738496.stm

*CHI 2001 Proceedings Volume 3, Issue 1, pp.490-497*

*CHI Letters volume 2, issue 1, pp. 161-168.*

*Proceedings of the 15th International ACM/SIGIR Conference*

*Journal of Environmental Psychology, volume 4, pp. 323-335*

*CHI 1997 Proceedings, pp. 267-274*

*BCS HCI Specialist Group, Proceedings of the 5th conference, Sep 1989*

*CHI 1997 Workshops, Nav ’97 Report*

The MIT Press

Human Factors and Web Development. Edited by Forsythe, C, Grose, E and Ratner, J.
*CHI '95 Proceedings*

*Proceedings of the Hypertext II Conference*

*Communications of the ACM, Volume 33, Number 3, pp. 296-310*

New Riders Publishing

*CHI Letters volume 2, issue 1, pp. 257-264.*

*CHI '95 Proceedings*

*CHI '95 Proceedings*

*Submitted*

Shneiderman, B. (1998). Designing the User Interface 
Addison Wesley Longman, Inc.

*ACM Interactions, November 1997, Issue IV.6*

Sullivan et al. (2000). When Kids Use the Web: A Naturalistic Comparison of Children’s Navigation Behaviour and Subjective Preferences on Two WWW Sites. 6th conference on Human Factors and the Web [online]
Available at http://www.pantos.org/ts/papers/wikutw/
Last accessed 28/04/2002


Appendices

Appendix A – Lessons learnt from the project experience

From the beginning of the project I realised that the Easter vacation was going to be a crucial time for my project. I kept to the project schedule (Appendix B) loosely but my major objective was to complete the websites and test the navigation aids before the Easter break. This meant that I would have all the data I needed from the experiments to enable me to proceed with writing up my final report. Producing the websites took longer than anticipated, but this was counterbalanced since I was able to carry out all the experiments in a couple of days.

One piece of advice I would pass on to students about to commence a project, is to produce their bibliography with full reference details as they perform their background reading and report writing. During my background reading I kept a list of the papers and books which had been relevant to my project. From the period where I produced the mid-project report onwards I began constructing the bibliography that would become part of my final report. Unfortunately I was lazy when I did this, adding incomplete references just to get an idea of the number and range I had read. The incomplete references were meaningful to me, but a reader would have had problems locating the papers and books from the details I had included. The main problem with my approach to this was that during the final week I had to go and find all the books and papers again and add the full references. Many of the papers I had printed and were readily available to me, but some I had to find online again, or in the case of books they had been returned to the library. This was time consuming and would have been unnecessary had I written the references in full first time. One thing I was happy with was the way in which I approached the draft chapter submission. This was a required deliverable to be submitted along with the mid-project report. The chapter I submitted was the background reading. I chose this chapter since at that stage background research was my primary activity. Although the chapter I submitted was not the finished article as it is presented in this report, I was reasonably happy with it and much of it remained unchanged. This was helpful since it meant I didn’t have to rewrite the chapter when I came to produce my report. It was also useful to gain feedback from both my supervisor and my assessor on the draft chapter. Although there were no marks available at the mid-project stage, approaching the draft chapter submission with serious effort is useful as it can indicate whether your writing is appropriate for the level of project being attempted.

I was also pleased with the response from course-mates when I asked them to participate in experiments. I conducted my experiments at a time when most people were working on coursework, luckily my experiments did not last very long. I would advise anyone planning on using students for experiments to try and choose a time where coursework deadlines are not so close.
### Appendix B - Project Schedule

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- **Mid-Project Report Due**
## Appendices

### Project Schedule Continued

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Appendix C – Paper detail used to construct website

These paper details show the format of the data file used by the HTML-building program to construct the leaf nodes of the website. Shown here are the first fourteen papers. The rest were not included since it was deemed unnecessary as forty pages were required to display the 130 paper details.

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<td>Sirigu, Duhamel, Cohen, Pillon, Dubois + Agid</td>
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Recent neuroimagery findings showed that the patterns of cerebral activation during the mental rehearsal of a motor act are similar to those produced by its actual execution. This concurs with the notion that part of the distributed neural activity taking place during movement involves internal simulations, but it is not yet clear what specific contribution the different brain areas involved bring to this process. Here, patients with lesions restricted to the parietal cortex were found to be impaired selectively at predicting, through mental imagery, the time necessary to perform differentiated finger movements and visually guided pointing gestures, in comparison to normal individuals and to a patient with damage to the primary motor area. These results suggest that the parietal cortex is important for the ability to generate mental movement representations.

<table>
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<tr>
<th>Knowing where and getting there: A human navigation network</th>
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<tr>
<td>Maguire, Burgess, Donnett, Frackowiak, Frith + O'Keefe</td>
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The neural basis of navigation by humans was investigated with functional neuroimaging of brain activity during navigation in a familiar, yet complex virtual reality town. Activation of the right hippocampus was strongly associated with knowing accurately where places were located and navigating accurately between them. Getting to those places quickly was strongly associated with activation of the right caudate nucleus. These two right-side brain structures function in the context of associated activity in right inferior parietal and bilateral medial parietal regions that support egocentric movement through the virtual town, and activity in other left-side regions (hippocampus, frontal cortex) probably involved in nonspatial aspects of navigation. These findings outline a network of brain areas that support navigation in humans and link the functions of these regions to physiological observations in other mammals.

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<th>Cognitive space: Using virtual reality for large information resource management problems</th>
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Virtual Reality Technology: A Tutorial
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Virtual Reality: An instructional medium for visual-spatial tasks
Regian, Wesley, Shebilske, Wayne + Monk
1992
training
No abstract available

Defining Virtual Reality: Dimensions Determining Telepresence
Steuer
1992
veDef
No abstract available

Telerobotics
Sheridan
1989
tele
No abstract available

Interaction styles and input/output devices. Special issue: Human-computer interaction research agendas
Jacob, Leggett, Myers + Pausch
1993
devices
No abstract available

User Study Comparing Head-Mounted and Stationary Displays
Pausch, Schackelford + Proffitt
1993
desktop
No abstract available

A Methodology for Choosing Data Representations
Robertson
1991
techVis
No abstract available

Visualisation and Analysis Using Virtual Reality
Ribarsky, Bolter, Bosch, Teylingen
1994
techVis
No abstract available

What are Virtual Environments?
Ellis SR
1994
veDef
No abstract available
Appendix D - Tasks for website testing

Section One
1. Locate the following paper,
   Roscoe, Airbourne displays for flight and navigation

2. Locate the following paper,
   Editorial, Back injury at work: a new beginning for prevention

3. Locate the following paper,
   Hindmarsh, Fraser, Heath, Benford + Greenhaigh, Object focussed interaction in collaborative virtual environments

Section Two
1. How many papers have Slater and Uosh collaborated on in the field of Presence in Immersive Virtual Environments?

2. How many of the papers in the Mental Rotation section have abstracts available?

3. How many papers are there on the theme of Visualisation?
   (Hint: there may be more than one group)
Appendix E – Graphs displaying results from website experiments (time in seconds)

Times for Task 1.1

Times for Task 1.2

Times for Task 1.3
Appendices

Times for Task 2.1

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Times for Task 2.2

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Times for Task 2.3

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