# Traversing the Web: Mobility Heuristics for Visually Impaired Surfers

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***Abstract*— Movement, or mobility, is key to the accessibility, design, and usability of many websites. While some peripheral mobility issues have been addressed few have centered on the mobility problems of visually impaired users. We use our past work to address these issues and derive mobility heuristics from mobility models, use these heuristics to place mobility objects within a web page, and describe the construction of a prototype mobility instrument, in the form of a Netscape plug-in, to process these objects. Our past work extends the notion of movement to include environment, feedback and the purpose of the current travel task. Specifically, we likened web use to travelling in a virtual space, compared it to travelling in a physical space, and introduced the idea of mobility - the ease of travel - as opposed to travel opportunity.**

## I. Introduction

Movement through and around complex hypermedia environments, of which the web is the most obvious example, has long been considered an important and major issue in the Web[1] design and usability field [2], [7]. The commonly used slang phrase 'surfing the web' implies rapid and free movement, pointing to its importance among designers and users alike. It has also been long established [1], [3] that this potentially complex and difficult movement is further complicated, and becomes neither rapid or free, if the user is visually impaired[2]. Previously we have shown that virtual mobility can be likened to real world mobility, that solutions to real world problems can be applied to the web, and that models of mobility can inform our creation of mobility heuristics. *In this paper we show how these heuristics are created, applied, and implemented.*
The richness of visual cues presented to a sighted user are not appropriate or accessible to a visually impaired user [15]. For example, a sighted user will be able to assimilate the page structure and visual cues on that page within a few seconds. This information is also continually present (on the page) for refreshing the memory of the user quickly when necessary. To fully realise the problems involved we suggest that our sighted readers start their browser and limit the window size to the top left fifth of the screen (see Figure 1). Now browse a series of simple and complex web sites, and note the problems you have. We believe you'll find that:

1) You can't get a feel for what's on the page.

[1]Or hypermedia.
[2]here used as a general term encompassing the WHO definition of both profoundly blind and partially sighted individuals

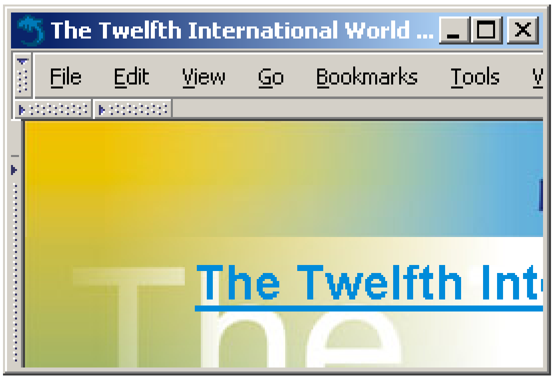


Fig. 1. Where Am I?

2) You don't know how long the page is or where you are on it.
3) You become disoriented.
4) Frames, tables, spacer images, and large images become obstacles.
5) There's too much detail for your viewing area and it's too complex.
6) The whole movement and travel experience is neither satisfactory nor enjoyable.

### *A. The Story So Far*

Our hypothesis is that travel and mobility within the web mirrors travel and mobility within real-world environments. We suggest that the Web community has typically concentrated on navigation and / or orientation rather than the whole travel experience, and that this neglect is crucial when dealing with browsing by visually impaired users. We therefore extend the definition of travel to mean: confident navigation and orientation with purpose, ease and accuracy within an environment. Work, including ours, has shown that:

1) Visually impaired users are hindered in their efforts to access the largest repository of electronic information in the world, namely the World Wide Web (WWW) [15].
2) A visually impaired user's cognition, perception, and worldview are highly egocentric, meaning that information feedback should be tailored to these mental processes [1], [15], [6].

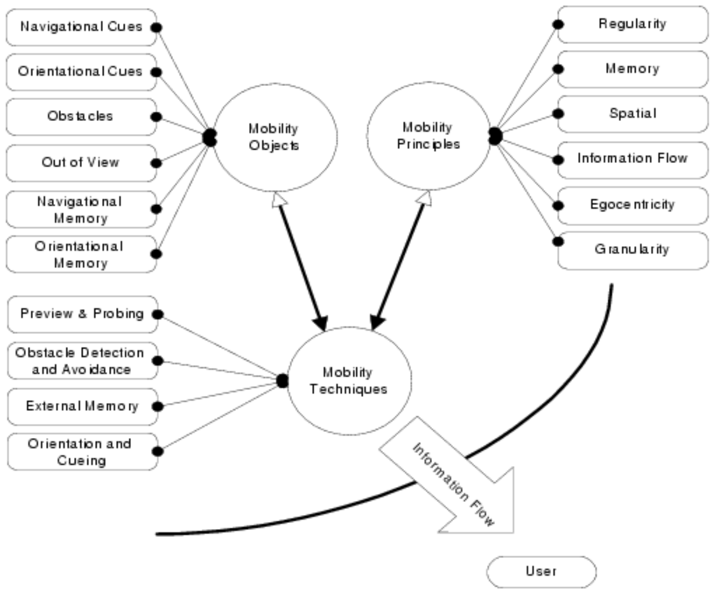


Fig. 2. Combined Objects, Techniques, and Principles

3) Visually impaired web travellers are at a severe disadvantage, when moving around the web, compared to their sighted counterparts [16]. This is because of the lack of explicit and necessary mobility information, implicitly available to a sighted user [15].
4) The absence of suitable mobility guidelines [20], mobility design and evaluation methodologies [8], technical implementations [19], [3], and work on holistic views (models) of mobility [4], [5], [2], [7], all hinder visually impaired users [9], [16].
5) W3C WAI, WebABLE, RNIB, AFB, and other guidelines focus on sensory translation by the graceful conversion of visual to auditory information, but take no account of mobility [15], [9], [20].
6) Hypertext design and evaluation methodologies, like HDM and SUE [8], pay little attention to mobility.
7) Web browsers for visually impaired users focus on examining the Document Object Model (DOM) or the Hypertext Mark-up Language (HTML) to present this information audibly, and do not consider implicit (or explicit) mobility information contained within the document [2], [7].
8) Solutions exist to real world mobility problems of visually impaired travellers [12], [14], [10]. These solutions can be applied (after some conversion) to the web, so that a visually impaired user's movement is enhanced [9].

### B. *In This Paper...*

In this paper we aim to support our ideas by suggesting mobility heuristics to enable us to find and create mobility objects within a page. We will then manually augment the page, and process it through a mobility tool. If on re-evaluation of the page we find clear improvement then it would seem that our theory is valid.

We continue our work by applying mobility objects to the World Wide Web, design a mobility markup schema to represent these mobility objects, and extend current user agents to include appropriate travel tools. Such tools would assist in the transformation of obstacles to cues, and actively support travel, rather than only navigation or content rendering.

We propose that by developing and examining mobility instruments (in this case a Netscape Plug-In) mobility techniques (within the instrument) can be enacted upon mobility objects (within the page) thereby facilitating enhanced movement around these complex hypermedia systems.

## II. Models into Heuristics

In our previous work we proposed a model of physical travel [18]. We defined the terms: Cue (familiar objects like landmarks), Obstacle (objects barring progress), Out-of-View (objects around a corner, say), and Memory (signs) and group them under the heading 'Mobility Objects'. We also created terms to represent actions performed on these objects: Preview and Probing (finding objects by investigation), Obstacle Detection and Avoidance (detecting and navigation around objects that may hinder our progress), External Memory (keeping information in plans, maps, charts, or route descriptions), and Orientation and Cueing (placing oneself in the environment based on familiar objects); we group these together as 'Mobility Techniques'. Finally, we define some terms to represent rules: Regularity (information must be predictable), Memory (assistance for mental mapping and survey knowledge should

be maximised), Spatial (support for spatial awareness should be increased so travellers can more easily track their position), Information Flow (simple information more frequently delivered, NOT large amounts of complex information delivered at one time), Egocentricity(descriptions of distance, journey, route, direction become associated with the traveller not the environment), and Granularity (information broken into a greater and more complex number of stages); we group these as 'Mobility Principles'.
By examining generic mobility objects, mobility techniques, and mobility principles, and the relationships between them (see Figure 2) we can enable the formulation of heuristics to assist web mobility. We convert our model into a form that can be used to increase visually impaired mobility on the web by defining a minimum set of heuristical methods (see Table I) that enable the standard generic mobility items to be specifically applied. Therefore, our mobility model is supported and adapted to be implementation specific.

*a) Fragmentation:* Fragmentation of the web page is key to facilitating good mobility for visually impaired people, because fragmentation encapsulates and facilitates the ideas of preview and probing, by splitting large complex documents into smaller more manageable parts. This fulfils our objectives of making the environment more regular, increasing information flow, supporting granularity, and adapting to egocentric behaviour. Therefore, separating content into smaller units makes travelling through it more manageable and meaningful [15].

*b) Overview:* Fragmenting a page means that some type of re-joining method must be employed. This means that previews of the fragmented areas will be clustered together to provide an overview and access mechanism for each fragment, aiding memory and spatial awareness and supporting information flow and egocentricity. The overview therefore encourages previewing of the clustered fragment links and consequently lowers the time taken for a visually impaired user to become familiar with the page content and structure. Fragmentation could also be useful in systems that have small viewable areas, like Personal Digital Assistants (PDAs) and mobile phones and communicators, due to their limited screen area.

*c) Concise Egocentric Descriptions:* Providing concise descriptions about the page and site, layouts and contents, aids memory and spatial awareness, and enables all web users to immediately better decide on where they want to travel or if they have reached their goal. In the case of visually impaired users egocentric descriptions should be used to dovetail in to the users mental and cognitive processes. These can be in the form of pop-up boxes to give this preview information, and indeed access to 'meta' tag content provides a useful mechanism of delivering this information if, both standard 'keyword', and custom descriptive contents are used to enhance mobility.

*d) Active Cue/ Obstacle Detection:* Cues and obstacles can be both active (placed specifically to increase mobility e. g. explicit hypertext markers, explicit markers around obstructions) or passive (placed for some other reason but still used as a mobility object e. g. hyperlinks to other pages). While passive cues are already generated in the form of headings and hyperlinks as part of the fragmentation, and the page design processes, active cues and obstacle information must be explicitly placed. These should be associated with something very significant on the document that a user must be aware of if they decide not to continue reading the document to its conclusion. This can be done by linking the target item to an item link at the top or within the document. In this way the first thing that a user is aware of is the fact that an active cue or obstacle exists and it points to a piece of important information, from either a content or mobility standpoint.

*e) Explicit Cue/ Obstacle Elicitation:* Obstacle and cue detection relies on knowledge of the page or site, however this knowledge is not normally explicitly present. In the context of visually impaired travellers, an image that is just used to space other content (commonly used in HTML) is an obstacle to a users progress regardless of whether it has an associated 'alt' attribute. Therefore a means of skipping over obstacles can be employed. This means that the obstacle is left, as it may be useful for some user groups, but those that wish to ignore it can do so without any bar to their progress. Similarly explicit cueing enhances the orientation of a user already facilitated by fragmentation.

We can now see more clearly (see Table I) how our heuristic definitions support our mobility concepts, and that these heuristics will enable (see Section III-B) better mobility once implemented.

## III. The Experiment

The Towel mobility plug-in was designed for evaluating our assumptions and design principles and was also intended to be as simple as possible to use. The method used was four fold, in order to accurately represent the real world mobility analogy.

1) We find out what mobility objects are present (and add those that are not) by application of our mobility framework (described in [9], [18] and not examined in this paper).
2) We manually mark-up any mobility objects found, and add those that are not found.
3) We implement a mobility plug-in (mobility instrument containing our techniques conforming to our principles) and apply it to the marked up document (see Figure 3 and Section III-B, later).
4) We use our resulting mobility rich hypertext within our browser to assist us in travelling around our site or document (see Figure 3).

### A. Marking up a Page

The plug-in is designed to work with XHTML pages (eXtensible Hypertext Markup Language [20]), that have been marked up with 'Towel Mobility Extensions' (TME) [17]. These are simply keywords written into the ID or CLASS attribute of any XHTML element. A TME object

| Heuristic | Supports Concept... | |
|---|---|---|
| Fragmentation | Principles | Regularity, Info. Flow, Granularity, Egocentricity |
| | Techniques | Previewing and Probing |
| | Objects | Out of View, Memory |
| Overview | Principles | Memory, Spatial, Info. Flow, Egocentricity |
| | Techniques | Previewing |
| | Objects | Memory, Cues |
| Concise Egocentric Descriptions | Principles | Info. Flow, Memory, Spatial, Egocentricity |
| | Techniques | External Memory, Previewing, Orientation |
| | Objects | Memory, Cues |
| Active Cue/Obstacle Detection | Principles | Info. Flow, Granularity, Spatial Awareness |
| | Techniques | Obstacle Detection and Avoidance, Orientation |
| | Objects | Cues, Obstacles, Memory |
| Explicit Cue/Obstacle Elicitation | Principles | Info. Flow, Granularity, Spatial Awareness |
| | Techniques | Obstacle Detection and Avoidance, Orientation |
| | Objects | Cues, Obstacles, Memory |

TABLE I

MODELS INTO HEURISTICS

is created such that information about its placement is encoded into the naming convention for the extension thus `TMEi:Location:Area:Type:Description`.

- **TMEi** Stands for Towel Mobility Extension inline tag. This tag is used as a prefix so that any user agent that understands TMEs can process them without destroying the HTML, XML, or XHTML. Tags can be placed in hypertext class or id attributes or as part of hypertext `SPAN` or `DIV` elements.
- **Location** The Location attribute represents the area that the TME tag represents and can have the value:
  - **Page** Specifying (`page`) as the location signifies that the information should be used when mobility around the page is required.
  - **Site** (`site`) signifies that information about the whole virtual area is encoded within the TME tag.
- **Area** The Area attribute specifies the part of the virtual environment under investigation and associates it with both the mobility models and the heuristics in terms of real world analogies.
  - **Memory** Memory (`mem`) represents information that is stored within the page to be referred to when required like route and layout descriptions.
  - **Environment** The environment (`env`) attribute represents information that is directly part of the actual hypermedia environment like hyperlinks and images etc.
- **Type** The Type attribute specifies the real world mobility metaphor used within the tag, and represents the context in which the information should be addressed.
  - **Navigation** A navigation (`nav`) context means that the tag should be used for movement from location to location, and should answer the question 'Where can I go?'.
  - **Orientation** An orientation (`ori`) context means the tag should be used to 'place' a traveller within a journey and should answer the question 'Where am I?'.
  - **Cue** A cue (`cue`) context is intended to draw the attention of the traveller to a particularly relevant piece of information within the journey. This information may be overlooked if it is not explicitly documented and therefore a users journey may be more difficult than it needs to be.
  - **Obstacle** An obstacle (`obs`) represents a mobility object that could cause problems when a user is journeying. This could be Java Applet that is not accessible or a HTML frameset that cannot be view properly.
  - **Out-of-View** An out-of-view (`vws`) context is used when a clusters of information cannot be read within 20 seconds. It is a way of creating summary information so that a traveller can quickly overview a page or site.

Description — The description represents a simple and explicit textual description of what the tag represents and the mobility information stored within it.

It is intended that in the future this TME mark-up will be automatically inserted, with only minor designer intervention required. However for our prototype version we manually marked up a page (see a manually decorated example source file of HTML [11]). While we used a standard plug-in (as a demonstration tool) this method is not flexible enough to provide a full mobility system, therefore the plug-in should be re-built as a 'helper' program, utility, or application. Travel rendering techniques have not been part of this research, and therefore all travel information has been rendered textually. However, it is envisaged that more sophisticated techniques will be required.

### *B. Heuristics into Implementation (The Browser Plug-In)*

The Towel plug-in produces a series of fragmented web pages, decorated with generated information derived from the placement of the TME objects. The plug-in is loaded when the browser encounters an XHTML EMBED element within the unprocessed hypertext file signalling that there are TME objects available. Once loaded the plug-in is driven by a series of keystrokes, which both activate and control its operation. These are function keys and are therefore all easily accessed by both visually impaired and sighted users.

When the plug-in is activated the TME objects are processed and the page fragmented and saved as separate local hypertext files with an automatically generated preview page. This page preview is a clustering of hyperlinks to the individual page fragments. Each hyperlink is post-fixed with a word count of the target document so that a user knows what to expect when the fragment is reached. In this way orientation to the page contents is much quicker.

The mobility objects representing external memory, all be they limited, are also processed so that a memory overview of the page and site content and layout are created. These, external memory aids are implemented such that the layout and content are presented as pop up message boxes which can be viewed at any time by using a hotkey. Each generated file has hyperlinks to move through the fragment set and to move back to the preview, so that the travel analogy is maintained along with the regularity of the environment (see Figure 3 pane 3). This regularity is important to visually impaired users because it enables a degree of predictability, and this predictability can often compensate for some of the loss in visual cues.

The preview page, and hence the fragments, can now be accessed from the main browser window (see Figure 3 pane 2). Therefore, egocentricity is also supported because the fragments and indeed the preview itself can be viewed in any sequence at any time and movement can occur in any direction, which means that the user chooses the way they move around a document and not the hypertext designer or the user agent developer. Additionally the links on the fragment to fragment journey are described in relation to the previous page and not as absolute references, which naturally aids this sense of egocentricity. This means that our mobility instrument supports our critical mobility features:

1) Regularity of the Environment
2) Egocentricity
3) Spatial Awareness

Further, as part of the fragmentation process the obstacle and cueing information are inserted into each fragment (see Figure 3 pane 4 and 5). This information is required at the time the fragment is accessed and not with the preview, as this would create unwanted information overload for the user.

Obstacles are dealt with by placing a hyperlink to an hypertext anchor `'name'` attribute at each end of the obstacle so that by selecting the hyperlink the user can jump either forwards or backwards over the obstacle (see Figure 3 pane 5). Therefore the obstacle is retained in case the user finds it useful, but it can be avoided if required. This system requires user intervention in that the user selects the obstacle 'jump' hyperlink to avoid the obstacle itself. However, another solution is that the obstacle could be removed completely from the page and placed in another location, linked by a hyperlink, so that the flow of the page content is not broken and so that a user needs take no action if the obstacle is not required.

Cueing is implemented by placing a hyperlink at the top of the fragment. This link is joined from the top of the fragment to the cue destination within the fragment (see Figure 3 pane 4) by an anchor `'name'` tag (as for an obstacle). In this way a user immediately knows of any important mobility information contained within the fragment. This cueing information means that users travelling through a journey can rely on explicit cues and not just those that may be provided like titles and section headings. In this case the traveller knows that the hypertext designer has seen fit to explicitly mark cues that they feel will be useful.

Even this simple system goes towards addressing most of the real-world issues investigated in our Web-Mobility Section (see II), and it does so by applying the advised solutions based on our enhanced mobility targets.

### *C. Evaluation*

We conducted our experiment by first applying our craft based framework [13] to seven sites representing a cross-section of the type of site available, from dynamic, through static, to document oriented locations. The analysis first looked at two dynamic sites (IMDB and BBC), then a document oriented site (the W3C site), next three static sites where analysed (the Hypertext2000, RNIB and AFB). Finally the web site for this project (the Towel project) was investigated. This site was created as the start of the project before any firm ideas where formulated on virtual mobility and so represents a snap-shot of our ideas on web site design before any investigations took place.

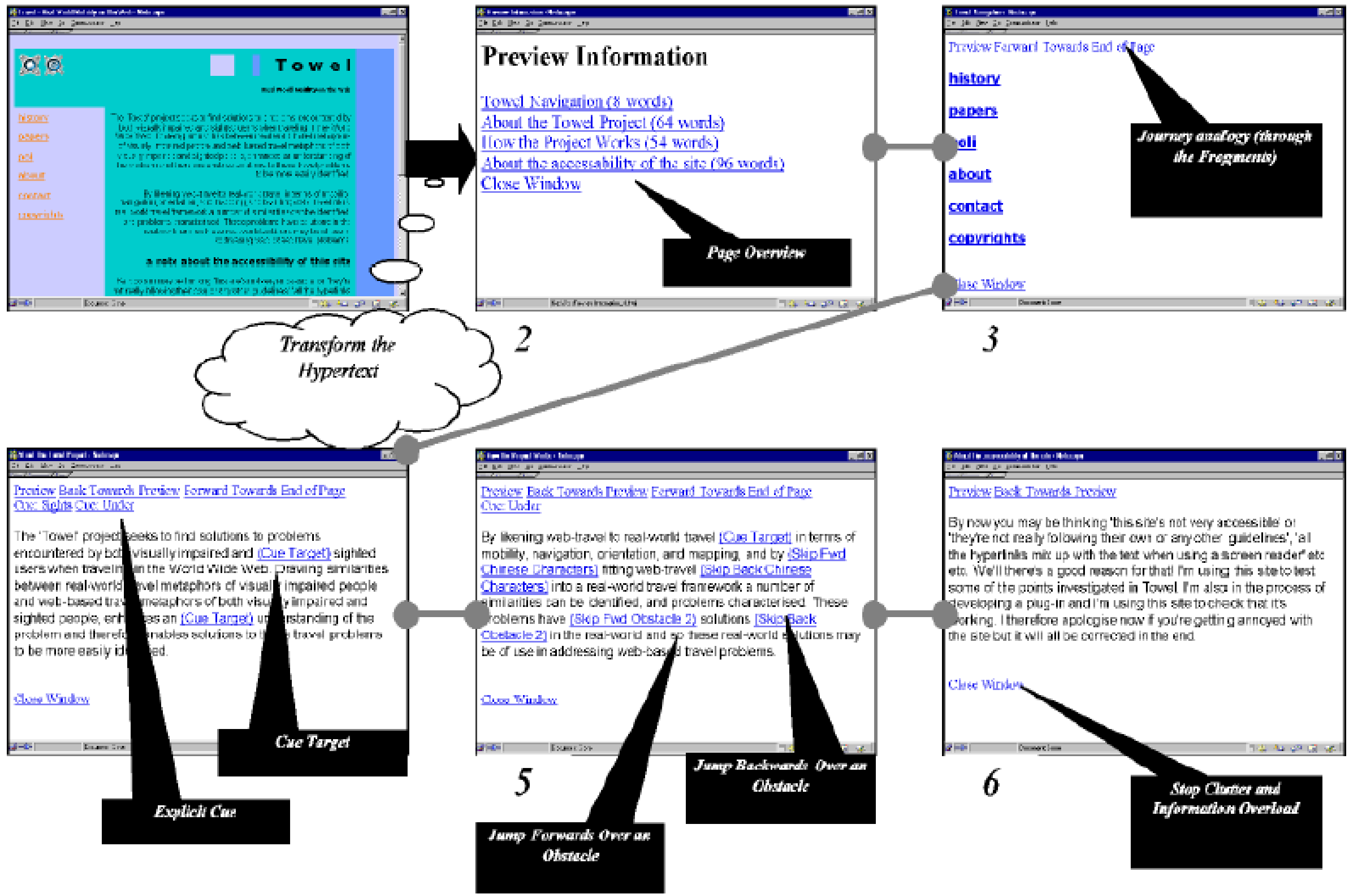


Fig. 3. Plug-In Output

We analysed all sites from both a sighted and visually impaired users perspective.

We then downloaded a page each from the IMDB and Hypertext2000 sites and modified them in accordance with the results of the first application of our framework. We also made modifications directly to the Towel website, and then re-evaluated the modified information.

These evaluations where performed along the two tracks of:

*f) Evaluation by the User:* This evaluation took the form of observing the responses of sighted and visually impaired users when moving around the processed 'Towel' test page. Users were asked a series of questions similar to those in the Pilot Study [16], and their responses where noted. We also asked more general questions regarding how the user 'felt' about the reformulated pages, how easy they thought they where to move around in, and what improvements could be made. It was also explained that we where testing the ease of movement and not the visual style and so comments about presentation where excluded.

It was found that the fragmentation of the page enhanced visually impaired users movement around, and cognition of, our test pages. Both groups said that they gained a greater understanding of both the page and site structure, and this was particularly apparent for visually impaired users. Small chunks of information worked best however some users commented that this would increase the number of clicks to get to some information on the page. On the whole the responses where positive.

The preview information enabled the user to make a quick decision as to whether to investigate the page further or to move on to a different page. In fact visually impaired users found this far more useful than the sighted user, as these preview descriptions made visually implicit information explicit. Users also suggested that more information about a link destination should be automatically included so that they didn't have to directly investigate the target node.

When investigating the page the journey metaphor of movement cues along the top of the document were found to be particularly helpful in guiding a user through the page fragments. They were useful in enabling orientation to both the page structure and the fragments themselves. This information was mainly helpful to the visually impaired users as the sighted individuals could easily orient themselves by the visual information present within the document. We expected this to be the case as work on this type of 'indexed guided tour' has previously been seen in HDM [8], in reality we have just extended this metaphor to encompass movement around a set of page fragments.

The notion of obstacles is promising, especially for large obstacles that take up a large amount of screen space. However, the users did suggest that the obstacle be removed from the page, and a suitably descriptive hyperlink inserted, so that user intervention is not required when travelling through the fragment. The 'skip' metaphor is helpful but were a little laborious then tabbing from link to link, however obstacle removal would solve this problem. Unfortunately link removal also creates problems, for instance if a menu becomes an obstacle when it has been encountered a number of times then removal would mean that navigation would be hindered. A compromise would be to 'skip' page / site 'furniture' and remove all other obstacles.

Cues also seem to be useful in drawing a users attention to specific significant items within the page or journey. This was the case for both users, however they also felt that the inclusion of a mechanism to define their own cues to be filtered into the page when loaded would be an advantage.

Finally, the user presentation of page and site, content and layout where found to be not as initially useful as we had expected. This seemed to be because either too much or too little information was present and this information did not change with the journey.

*g) Evaluation by Reapplication of the Mobility Framework:* By reapplying the Mobility Framework [9], [18] to the web sites after the pages had been updated with Towel Mobility Extensions (TME), we could evaluate how effective the mobility instrument (our plug-in) implemented the mobility techniques on the mobility object now coded into the page. It also enabled us to see if the mobility framework was suitably applied to the site by the instrument, because if not, the overall scores for that system would decrease.

In each case the increase in ratings for sighted and visually impaired users where similar across sites. After placement of the TME there was little change in the usability ratings for sighted users. In fact on examining the usability summary and the usability statistics it could be seen that there was very little room for improvement as the initial scores for each site where in the late 80% and early 90%. For the visually impaired user however the story is quite different because with usability ratings of 74%, 60%, and 51% for Towel, IMDB and Hypertext2000 respectively before placement of the TME, the scope for change was far higher, and indeed increased to an average of 86%.

Major improvements can be seen within environment mobility objects. These improvements are mainly concerned with making inventory items more visible and explicit if used as mobility objects. Obstacles within the environment for both sighted and visually impaired users are reduced to approximately zero as are out-of-view items. Problems existed with the accessability of the descriptions and preview of destinations of objects within the environment. This lead to these objects becoming either obstacles or out-of-view items. Once these issues had been addressed during re-formulation of the page (by the plug-in) the number of 'problem' objects dropped significantly. An effect of this is that cue comprehension (both navigation and orientation) by visually impaired users doubles after re-formulation because the number of cue objects are increased as obstacles and out-of-view items are decreased. Sighted comprehension of these cues only slightly increases because they are mainly visual and therefore are not classed as obstacles (to sighted individuals) when the framework is applied to the original site. Consequently there is less room for improvement, and any improvement that does occur is mainly associated with increased preview of out-of-view objects.

There are also increases with regard to memory objects but this is not as pronounced as with objects within the environment. The causes of obstacles and out-of-view objects identified in the original sites where centered around the context and description of mobility objects defined within the mobility inventory, and around the description and placement of disjoint information sections within a page. These ‘causes’ where addressed once the page was passed through the Plug-In thereby reducing the number of ‘problem’ memory objects.

The overall rating for the page has therefore been increased substantially and this increase has brought the mobility information available to a visually impaired user into line with that useable by a sighted user.

Problems do still exist as we have not yet achieved an optimum 100% mobility rating of all mobility types. However, the lessons learned by the re-application of the framework have feed into our understanding of points that we need to address in the future.

### D. Lessons

*h) Implementations:* Through our evaluation it has become evident that there are a number of lessons to be learnt when considering designing and building new pages and user agents.

Journeys should be monitored so the positional information is known, in this way cues and obstacles should be decided-on when they are near to the traveller and a user can state that obstacles should no longer be regarded as obstacles for them personally.

The presence of cues and obstacles should be included with the preview information. These should be just either a ‘C’ or ‘O’ merely to indicate their presence and so as not to increase information overload. External Memory should keep journey metrics, dynamic maps, old journeys, and allow the exchange of information between travellers.

External Memory should also allow the marking of interesting points for later investigation and should create a ‘road’ by placing junctions of hypertext links that you may want to follow at present or later. Either-way this map should be kept for the session and permanently if the user decides.

User agents should enable the storing and sharing of journey information in much the same way as one person will relate a real-world journey to another. Agents should also enable look ahead on hyperlinks to create better preview information, in this way real content from the linked page could be used to augment user choice. The marking of pathways in an egocentric manner reinforces the users perception of familiarity with the journey and enables them to decide on the relevance of objects for this particular journey and the ability to investigate the context when a user has tabbed to a non-descriptive hyperlink would be useful. Some web sites still user non-descriptive links (for example ’Click Here’) however, if the user agent could work backwards and distinguish the context by the preceding sentence comprehension can be increased.

*i) Design:* We found that most websites we examined had many travel objects few of which were cues because mark-up was misused. In such situations, user agents would be obliged to deduce the presence and identification of objects, infer their role, and choose an instrument to access and use them, through examination of the pages, site, and travel process. While this is not impossible it is difficult, and so we feel it is better to explicitly incorporate travel into design and hypertext design methodologies because the designer may be in a better position to decide about what a hypertext construction is in terms of mobility. however, applying the framework manually and then encoding the mobility mark-up into the web page has drawbacks because:

1) It can take along time.
2) Placement and encoding of the mobility objects can sometimes be ambiguous.
3) It may pose a problem for a designer *unskilled in mobility issues*.
4) It may pose a problem for a designer *unskilled in visual impairment*.

Therefore, a useful development would be a system to automatically apply the mobility framework and either, insert hypertext mobility information, or reformulate the page to increase its ease of mobility. The designer may have to respond to a number of questions when the system cannot practically deduce what mobility information is necessary, however, typing simple information to infrequent prompts is much easier than directly coding and placing HTML.

The system would also require a re-implementation of the mobility framework to move it from a craft based method to an engineering based method which could be applied my a machine.

### E. Further Evaluation

Defining a series of mobility roles is useful because it enables mobility objects to be characterised and negative (or ‘problem’) objects, such as obstacles, to be highlighted and changed. However, the scale of this ’usefulness’ could only be fully understood after an initial study and comparison of original and re-formulated sites had been made. Now that problems have been identified, lessons learnt, and improvements suggested, further work can be carried out and further evaluation of this work needs to be completed.

## IV. Conclusions and Further Work

Applying knowledge about real world mobility to web based mobility problems can enhance the travel experience for visually impaired users. The use of fragmentation to assist preview and appropriate knowledge feedback will increase the mobility of users within many virtual journeys, and therefore solve many of the mobility problems encountered frequently in web based travel.

We *Conclude* that the Towel system adds two more stages of complexity to standard web systems, by manually pre-marking an XHTML page with mobility information, and

then by processing that information in an appropriate way, by means of a plug-in, when the XHTML page arrives at the clients browser. These additional stages can be justified but simpler alternatives may also be found.
Originally, we felt that extensions to the proposed system (described in section III-D) should be made. These would incorporate automatic marking-up of pages with mobility information, browser mobility-application integration, and use of the Extensible Mark-up Language (XML) so that mobility information could be portable between systems. However, we now think that due to the nature of the web this approach is neither flexible or appropriate. Eventually, it may be possible to process hypertext information on-the-fly based on a user pre-defining a set of mobility options (elements or combinations of elements) that represent mobility objects to them personally, however this is not yet the case. We conclude that for a truly universal solution the lessons described here (paying particular attention to section II) should be incorporated into the WAI guidelines as heuristical methods for easier page and site traversal.

We propose that *further work* needs to be undertaken to extend the framework to encompass a more systematic purpose and to account for current focuses of activity, we needed to more closely relate the work to hypertext usability frameworks such as SUE, extending their notion of context observability for example [18]. More importantly however, we need to redesign the framework and investigate the benefits of a more engineering centered approach so that tools can be created to process a page before reaching the user.

*Finally*, this work has been useful in leveraging real world mobility solutions to build a prototype mobility plug-in for the World Wide Web and in providing insight into how web mobility can be increased for all users. We have shown that addressing the travel and mobility issues of visually impaired users also addresses those of sighted users too, thereby making surfing the web easier for everyone.

## REFERENCES


[1] M. Brambring. Mobility and orientation processes of the blind. In D. H. Warren and E. R. Strelow, editors, *Electronic Spatial Sensing for the Blind*, pages 493–508, USA, 1984. Dordrecht, Lancaster, Nijhoff.

[2] C. Chen. Structuring and visualising the www by generalised similarity analysis. In *Proceedings of the 8th ACM Conference on Hypertext and Hypermedia*, New York, USA, 1997. ACM Press.

[3] A. Chieko and C. Lewis. Home page reader: Ibm's talking web browser. In *Closing the Gap Conference Proceedings*, 1998.

[4] R. P. Darken and J. L. Sibert. Wayfinding strategies and behaviors in large virtual worlds. In M. J. Tauber, V. Bellotti, R. Jeffries, J. D. Mackinlay, and J. Nielsen, editors, *Proceedings of the Conference on Human Factors in Computing Systems : Commun Ground*, pages 142–149, New York, 13–18 1996. ACM Press.

[5] A. Dillon and M. Vaughan. It's the journey and the destination: Shape and the emergent property of genre in evaluating digital documents. 3:91–106, 1997.

[6] A. G. Dodds. The mental maps of the blind. 76:5–12, January 1982.

[7] R. Furuta. Hypertext paths and the www: Experiences with walden's paths. In *Proceedings of the 8th ACM Conference on Hypertext and Hypermedia*, New York, USA, 1997. ACM Press.

[8] F. Garzotto and M. Matera. A systematic method for hypermedia usability inspection. *New Review of Multimedia and Hypermedia*, 3:39–65, 1997.

[9] C. Goble, S. Harper, and R. Stevens. The travails of visually impaired web travellers. In *Proceedings of the 11th ACM Conference on Hypertext and Hypermedia*, pages 1–10, New York, USA, 2000. ACM Press. Towel Project (http://www.man.ac.uk/towel) - Winner of the Doug Engelbart Award for Best Paper at ACM Hypertext 2000.

[10] P. Green and S. Harper. An integrating framework for electronic aids to support journeys by visually impaired people. In *International Conference on Computers Helping People with Special Needs*, 2000.

[11] S. Harper. Towel TME example. WWW. http://www.man.ac.uk/towel/TMETest.html.

[12] S. Harper. Standardising electronic travel aid interaction for visually impaired people. Master of philosophy in software engineering, UMIST, Manchester, UK, September 1998. POLI Project (http://www.man.ac.uk/towel).

[13] S. Harper. *Web Mobility for Visually Impaired Surfers (The Towel Project)*. Doctor of philosophy in software engineering, University of Manchester, Manchester, UK, June 2001. Towel Project (http://www.man.ac.uk/towel).

[14] S. Harper and P. Green. A travel flow and mobility framework for visually impaired travellers. In *International Conference on Computers Helping People with Special Needs*, Germany, 2000. OCG Press. POLI Project (http://www.man.ac.uk/towel) - under the auspices of the UNESCO.

[15] S. Harper, R. Stevens, and C. Goble. Towel: Real world mobility on the web. In J. Vanderdonckt and A. Puerta, editors, *Computer-Aided Design of User Interfaces II*, pages 305–314. Kluwer Academic, 1999. Towel Project (http://www.man.ac.uk/towel).

[16] S. Harper, R. Stevens, and C. Goble. A pilot study to examine the mobility problems of visually impaired users travelling the web. *The ACM Special Interest Group on Computers and the Physically Handicapped Newsletter (ACM SIGCAPH)*, (68), September 2000. Towel Project (http://www.man.ac.uk/towel).

[17] S. Harper, R. Stevens, and C. Goble. Prototype mobility tools for visually impaired surfers. In *Proceedings of the 12th ACM Conference on Hypertext and Hypermedia*, New York, USA, 2001. ACM Press. Towel Project (http://www.man.ac.uk/towel).

[18] S. Harper, R. Stevens, and C. Goble. Web mobility guidelines for visually impaired surfers. *Journal of Research and Practice in Information Technology Special Issue on HCI (Australian Computer Society)*, 33(2), 2001. Towel Project (http://www.man.ac.uk/towel).

[19] J. M. Spool. Web site usability: A designers guide, user interface engineering. WWW, 1997. http://world.std.com/ uieweb/index.html.

[20] W3c. Website. WWW, Feb 2003. http://www.w3c.org.