UNIVERSITY OF SOUTHAMPTON

INTEGRATING ADAPTIVITY INTO WEB-BASED LEARNING

by

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A thesis submitted in partial fulfillment for the degree of Doctor of Philosophy

in the
Faculty of Engineering and Applied Science
Department of Electronics and Computer Science

June 2003

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRONICS AND COMPUTER SCIENCE

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Adaptive hypermedia is an emerging technology that changes the conventional way of presenting information online. Instead of displaying a static page, information can now be adapted dynamically to users, where different users with different needs, interests and domain background are directed to different pieces of information. This idea has attracted the educational community in recent years to develop adaptive systems and applications for learning purposes. Many techniques and methodologies have sprang from these developments for organising the content (domain modeling) and capturing information from the users (user modeling) in order to implement the adaptive mechanisms.

This thesis proposes two methodologies that build upon existing methods in both domain modeling and user modeling for adaptive hypermedia, particularly in the educational context. This work demonstrates the use of effective reading speed to present a novel way of modeling the user's browsing history in adaptive hypermedia. Also, in terms of domain modeling, the work proposes the use of a keyword representation technique to free the domain expert from their heavy involvement in the conventional way of organising the content for adaptive hypermedia. As a result, a web-based medical learning application, namely JointZone, is developed to embrace these new methodologies. JointZone's content is made adaptive using two adaptive techniques: knowledge-based link hiding and browsing history-based link annotation. The thesis also presents a usability study and an evaluation that assess the impact and effectiveness of these adaptive techniques in web-based learning.

A secondary objective of this work is to explore how better linkage between information entities on the web can be achieved through the adoption of linkbases. The thesis hence also demonstrates methods for generating structural, associative and referential links to provide an additional dimension to the conventional methods of linking information in a web-based learning application.

Contents

List of Figures

List of Tables

Acknowledgements

I would like to acknowledge Professor Wendy Hall for her vision, encouragement and support in this research.

A sincere gratitude to the Arthritis Research Council for funding the project. Thanks to Ray Armstrong (Rheumatology Consultant at the Southampton General Hospital) for providing the learning materials which the research is based on and Pat Maier (Centre for Learning and Teaching) for her advice in the teaching and learning perspective.

I would also like to thank Sanghee Kim (Research staff in IAM) for coding the text processing program. Thank you especially to Gary Wills (Senior Research Fellow in IAM) for his sound guidance in the statistical analysis aspect of the research. Also, Jon Hallet and Alistair Riddoch for their substantial server-side support in the technical part of this work. Also the rest of the great team of the IAM researchers for their technical support and advice.

Thank you also to the following person who proof read this thesis: Yue Teng Tang, Pat Maier, Gary Wills, Mark Weal and Christopher Bailey.

Above all, I want to thank God for His grace, whenever work seems unraveling for me, He is always faithful in knitting all things back together for good.

To my parents, my three sisters and my brother, for their love and continuous support all these years.

Chapter 1

Introduction

1.1 Motivation

The irresistible rise of computer and internet usage has greatly enhanced the opportunities for education, which traditionally has been mostly confined to conventional textbooks and classroom-based learning. Online learning, which was made possible by the expansion of the internet, has been influential towards modern education especially in higher education. This is evident in the increasing availability of educational materials online, ranging from simple online lecture notes to more complicated tutoring systems. Computers are now serving a vital role in knowledge transfer to students; complementing the traditional roles of teachers and textbooks.

In the early seventies, Computer Assisted Learning (CAL) came into the limelight with the emergence of Intelligent Tutoring Systems (ITS) (Sleeman and Brown 1982; Nwana 1990). The ITS approach focuses on building intelligent software that can act as a tutor to diagnose and respond to the needs of learners. However, critics have raised concerns that in ITS, the emphasis is on teaching (tutor) rather than learning (learner) (Boyle 1997). The earlier ITS applications such as SOPHIE (Brown, Burton, and Bell 1975), SCHOLAR (Carbonell 1970), Lisp Tutor (Anderson and Reiser 1985) and GUIDON (Clancey 1983) focused more on the teaching aspect of problem solving. They had very little learning materials integrated within the applications. Hence, the nature of learning was very much restricted to what and how the ITS was programmed to teach the students.

The development of hypertext and hypermedia shifted the focus from tutors to learners. In a hypermedia environment, users generally have the freedom to follow whatever links to wherever they want. They gain more control over the content and have the opportunity to navigate the hypermedia applications at their own pace (Laurillard 1987). Given the built-in browsing facility in this environment, students can plan, structure and sequence their learning experience. Research has shown that the increase in learners' control can increase the overall intrinsic motivation of the learners and leads to deeper learning through self-discovery of their own links within the information space (Becker and Dwyer 1994).

However, this free-exploratory environment can be counter productive with the possibility of students encountering 'cognitive overload'. Conklin described cognitive overload as '*the additional effort and concentration necessary to maintain several tasks or trails at one time*'(Conklin 1987). According to Thuring et. al. (Thuring, Hannemann, and Haake 1995), such additional effort with respect to hypermedia browsing is related to :

- *orientation*, users need to know their current location in relation to the whole information network,
- *navigation*, users need to constantly make navigation decisions as they move from one piece of information to another,
- *user-interface adjustment*, users need to spend time adjusting to the user interface of new applications.

All these can be too demanding on human information handling and processing capability. Therefore, a completely free learning environment is not to be encouraged (Halasz 1987).

A proper level of guidance without undermining the creativity and control of learners is an ideal solution. The emergence of Adaptive Hypermedia (AH) (Brusilovsky 1996), which we discuss in detail in Chapter 5 brings new flexibility and the capability of personalization into the conventional way of presenting learning materials online. It takes the synergy from the intelligent components of ITS and the free exploratory element of hypermedia to present an application that provides the *right* content to the *right* users at the *right* time and the *right* place.

1.2 Objectives and Scope

The objective of this work is to develop a web-based medical learning application through the use of hypermedia to provide a self-exploratory learning environment as discussed in detail in Chapter 3. This application aims to support students in the learning of declarative and procedural knowledge in Rheumatology as we discuss in Chapter 4.

The initial stage of this work is based heavily on the generation of content and its structural layout in the web information space. It highlights the implementation of links in hypermedia environment, which defines the way information is interconnected in an application.

The later stage of this work focuses on integrating adaptive features into the application to establish a personalised learning environment. This part of the work emphasises on developing methodologies for capturing users' information and content organisation for adaptation purposes. Ultimately our aim is to develop new adaptive features that could be implemented without dependence on the subject-expert. Our motivation is also to develop an adaptive hypermedia application that is based on a simple user model.

Evaluation is another objective of this work in order to produce findings on the quality of this work. A usability study was conducted on the application developed. This was followed by an evaluation which focused specifically on the effectiveness of the adaptive hypermedia techniques employed in the work.

1.3 Contribution

We has set out to integrate adaptive hypermedia features into a static web-based medical learning application. With this, we believe our work has contributed in two ways:-

- we have derived a user modeling approach which adopts the novel idea of using the 'individual effective reading speed' as a means to capture users' browsing history within an information space. The method was validated and proved to be more effective than existing methods to date.
- we have also derived a domain modeling approach which free authors from the dependence on the subject-expert to achieve an adaptive web application.

The work also presents an evaluation conducted with medical students. The results revealed clearly the effect of personalization in a web-based environment and gave new insights into the use of technology to support learning.

The application conforms to the core curriculum set by *The European League Against Rheumatism (EULAR)* and contributes to the learning of Rheumatology. It was targeted at, but not restricted to, university undergraduates. It serves as a full-fledged web-based learning application, including a unique synthesis of an adaptive hypermedia system, a situated learning environment and a dynamic network of links between different media types in the domain.

1.4 Thesis Structure

Chapter 2, *Background*, provides a background on the definition and philosophy of hypermedia. A few examples of hypermedia systems are given in this chapter.

Chapter 3, ***The Role of Hypermedia in Education,*** discusses the role of hypermedia in education to provide an outline of the contribution of hypermedia technology in teaching and learning.

Chapter 4, ***Implementation of JointZone,*** explains the implementation and the pedagogical values of the JointZone application by focusing on the system architecture, case studies implementation and link generation. The chapter ends with a usability study of JointZone.

Chapter 5, ***Adaptive Hypermedia,*** provides background on research in the area of adaptive hypermedia by giving an overview of user modeling, domain modeling and levels of adaptation. Examples of previous adaptive hypermedia systems are also presented.

Chapter 6, ***Integration of Adaptivity into JointZone,*** gives a detailed description of how adaptivity was integrated into JointZone.

Chapter 7, ***Evaluation,*** presents the evaluation conducted on the adaptive application. The results and their implications are discussed in relation to learning online.

Chapter 8, ***Conclusions and Future Work,*** presents the conclusions derived from this work and discusses future work in various possibilities.

1.5 Declaration

The work presented is the original work of the author and was undertaken within a collaborative research environment. The implementation in terms of coding was done by the author except the program for keyword extraction which was coded by Dr. Sanghee Kim of the IAM Research Group, University of Southampton.

Chapter 2

Background

This thesis draws on the fundamentals of hypermedia research which addresses the issues of information organisation, navigation support and browsing facility within an information space. This chapter will first give a brief history of the birth of hypermedia. Then it will touch on the general concept of hypermedia through discussions on nodes and links. Further elaborations on link types, link storage and linking mechanisms are presented in the same section. The chapter will end with five examples of hypermedia systems in order to give implementation overviews of hypermedia concepts.

2.1 A brief history of hypermedia

The history of hypermedia really began with Vannevar Bush's famous concept of the MEMEX, *'Memory Extender'* (Bush 1945). In MEMEX, data is stored on microfilm and projected onto the desk. The use of several projectors allow the viewing of more than one document at the same time. Bush envisioned the idea of retrieving information through association rather than arbitrary indexing (where information can only be retrieved through a single linear index). Bush described the possibility of applying the mechanism of the human mind which operates by association to connect pieces of information together. In this case, MEMEX would provide *links* between documents and *trails* (sets of links) that establish meaningful connection through the tangle of information.

This idea later inspired the invention of hypertext, a term coined by Ted Nelson as part of his Xanadu project (Nelson 1980). Ted Nelson defined hypertext as the non-sequential task of reading and writing of information. He proposed a new idea of information storage and retrieval of text by the use of links where new browsers can continually have access to old material through the mechanism provided by links.

2.2 Concepts of hypermedia

Hypertext and hypermedia are commonly used as two interchangeable terms. However hypertext refers to text only while hypermedia is the expansion of hypertext to include image, video and audio (W3C 1992). A hypermedia network is defined as a database of *nodes* connected by *links* (Halasz and Schwartz 1994). Each node can contain different information entities such as text, image, audio or video. Users navigate the hypertext network by activating a link anchor to reach a desired node. This model of nodes and links is the essence of hypertext and its design often contributes to the flexibility and functionality of a hypertext system.

2.2.1 Nodes and Links

Nodes are the most basic entity in a collection of information. The granularity of a node (the size of the node) often varies and is defined by the author of the information space. For example, a node can be in the form of a whole document consisting of contiguous text or a mixture of multimedia objects (text, images, audio and video). It can also be a span of text, which is part of the document or simply an image or a video clip. In the context of knowledge representation, a node can define one or more concepts based on the content it is delivering.

There is an extreme variation in the use of the term 'node' across various hypertext systems. In KMS (Akscyn, Mccracken, and Yoder 1988), a node is called a *frame*, which is a screen-sized work space. In NoteCards (Halasz, Moran, and Trigg 1987) and HyperCard (Goodman 1987), a node is defined as a *card* which is an electronic representation of the 3x5 inch paper notecard. And a node is generally referred as a *document* in Intermedia (Yankelovich, Haan, Meyrowitz, and Drucker 1988) and the World Wide Web (WWW) (Berners-Lee, Cailliau, Luotonen, Nielsen, and Secret 1994).

Links are the core component of hypertext and hypermedia. Links provide the ability to jump from one node to another, anywhere in the hypermedia space. Typically, a link ties together two resources, which are the link source and the link destination. The notion of linking facilitates a non-sequential mode of access as defined by (Nelson 1987). From a different perspective, links define the relationship between two or more nodes within a hypermedia application, thus allowing the visualisation of hypertext and hypermedia as a science of relationship management between documents (Isakowitz, Stohr, and Balasubramanian 1996). A collection of nodes relies on the link types to define the relationship between them. For example if two nodes are connected by an associative link, the link denotes that these two nodes are content-relevant. If a group of nodes are linked together through sequential links, this reflect that the nodes are structurally put together as sub-pages to a parent concept.

2.2.2 Linking Mechanisms

Hypermedia encompasses a wide range of linking mechanisms. The most widely used mechanism is *simple linking.* Simple linking connects a single source to a single destination via a uni-directional link (Figure 2.1). This form of linking is normally explicitly defined. It has been an enduring feature of hypertext from the early systems like HyperCard to today's WWW.

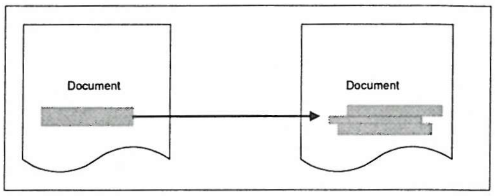


FIGURE 2.1: A simple link, from one link source to one destination.

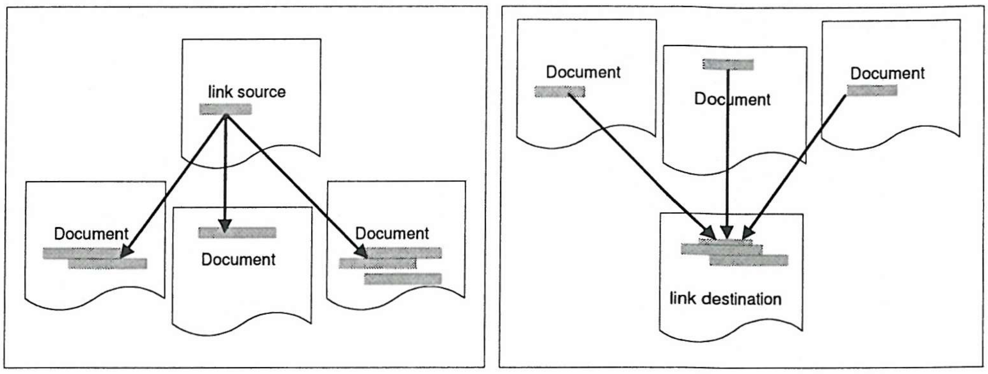
Multi-destinational or multi-sources linking ((Lowe and Hall 1996), p. 121)(Leggett and Schnase 1994) involves more than two participating link resources[1]. This link mechanism produces 'one-to-many' or 'many-to-one' links (Figure 2.2). *One-to-many linking* denotes multiple link destinations that expand from a single link source. An example is a single link from the link menus that branches out to a directory of multiple link destinations, as seen in Intermedia (Yankelovich, Haan, Meyrowitz, and Drucker 1988) and KMS. *Many-to-one linking* denotes multiple link sources connected to a single destination. This normally occurs in a glossary function where a glossary text is concurrently referenced by different documents, as in Microcosm (Fountain, Hall, Heath, and Davis 1990). This form of linking encourages information reuse but at the same time it can also create too many distracting identical links.

2.2.3 Link Storage Approach

Links created in the hypermedia need to be stored somewhere within the applications. Davis (1995b) made a concise summary of the different link storage approaches that exist to date:

Embed at the hot spot: Some of the earlier hypertext systems such as KMS and the recent WWW take this approach by embedding links within documents. However, the disadvantage of this approach is that once a document is removed, all links that point to this document need to be removed as well. This is hard to achieve

[1]Any addressable object that contributes to a link. i.e. document, parts of documents, images and query results.



(a) One-to-many link (b) Many-to-one link

FIGURE 2.2: Two forms of extended link.

as it is not possible to update documents owned by other users, as in the case of the documents in the WWW. As a consequence, the dangling link problem (Davis 1995a) arises where the hypermedia system fails to resolve a link because the document pointed by this link is removed.

Embed a pointer within the content, but store the link externally: In the second approach, links are stored externally in a link database (linkbase) but the pointers of the links, which act as markers to indicate the hot spots of a link, are embedded within the document, as in Sun's Link Service (Pearl 1989). With this separation of storage, tools can be built to update the links that are held centrally in a linkbase. In this way, the dangling link problems can be easily tackled.

Store both the link and pointers externally: This approach is taken by Microcosm where both links and pointers are held externally from the documents. The main advantage of this approach is that links can be created into or out of any read-only or third party's documents since there is no pointers needed to markup the links. This approach removes the dangling link cases but leads to inconsistency problems. When a document is edited, the character offset or pointers are disturbed, hence the links will end up pointing to the wrong position within the documents.

2.2.4 Link Types

A link type describes the relationship between the source and destination of a link, which is often based on semantic categories like 'glossary', 'example' and 'details' (Trigg 1983). The initial idea for link typing was to help users to get a better idea of a link target. However it was also argued that the availability of link types is only helpful if the user can distinguish between the different types of links (Harald, Obendorf, and Lamersdorf 2001). A number of classifications of links have been proposed but in most cases they are only applicable to their own specific hypertext system (Halasz, Moran, and Trigg 1987; Akscyn, Mccracken, and Yoder 1988; Fountain, Hall, Heath, and Davis 1990). There has been no attempt to date to standardize the classification of link types.

DeRose proposed that the definitions of different types of links are based on the logical structure (with units such as chapters, paragraphs) and the physical structure (with pages and lines) of an information space (DeRose 1989). Table 2.1 shows the typed links as proposed by DeRose.

Types of links	Descriptions
Associative links	- attach documents based on purposes defined by the user. - created on the fly.
Annotational links	- connect portion of text to information about the text through buttons or line markers. - one end of the links is predictable, i.e. next button.
Sequential links	- represent the aspect of document structure. - i.e. a section link to its sub-parts.
Taxonomic links	- lead to multiple locations and does not impose an order on them. - i.e. connect related groups of data in a lexicon, such as cross-references between words.
Implicit links	- exists when the target element appears within the context of the source document. - i.e. dictionary lookups, reference methods, bibliographic references.
Isomorphic links	- exists when target elements appears as name (rather than content) within the source document. - in cases where documents exist in several versions, the corresponding elements are linked to provide comparison.

TABLE 2.1: A classification of links by DeRose (1989)

2.3 Examples of Hypermedia Systems

A number of systems were designed to meet the functionality of hypermedia since its birth in the early eighties. Five of these systems are discussed in this section. The focus is on the implementation model of these systems, particularly in the linking aspect and also design's capability to support the navigation facility of the information corpus.

2.3.1 NoteCards

NoteCards is a computer environment designed to provide users with a 'semantic network' of electronic notecards interconnected by typed links (Halasz, Moran, and Trigg 1987). This semantic network serves as a medium for the users to work with a collection of ideas, where unrelated data can be integrated in an orderly fashion to bring out the interpretation of ideas. The system is used primarily for analysing information, constructing models, formulating arguments, designing artifacts and generally processing ideas.

Data Model: A notecard contains an arbitrary amount of information such as text, graphics and images. Links are used to interconnect individual notecard into a network of related cards. Each link is a typed and directional connection between a source card and a destination card. Users choose from different types of links to decide the best way to organize a network of notecards. The link anchor at the source card is identified by a link icon, which can be displayed as the title of the destination card or the type of the link. A *browser* is a specialised notecard that contains a structural diagram showing a network of cards with their links. On the browser, the notecards are represented by boxed titles and the links are represented by lines between the boxed titles. A variety of line styles are used to distinguish between different links. *Fileboxes* are specialised cards used to organise large collection of notecards. It encourages a hierarchical category structure of notecards for storage and retrieval purposes. Every notecard is required to be filed in at least one filebox.

2.3.2 KMS

KMS which stands for Knowledge Management System was developed in the early 1980s to help organizations manage their large-scale knowledge management tasks (Akscyn, Mccracken, and Yoder 1988). It supports a wide range of applications, such as electronic publishing, online manuals, project management, financial modeling, issue analysis, bulletin boards and computer aided instructions.

Data Model: The heart of KMS is a database storing screen-sized workspace called frames. Frames may contain any combination of text and graphics. Each frame can be linked to another frame or used to invoke a program. Users navigate from frame to frame by pointing the mouse cursor at an item on the frame and clicking on the mouse button. KMS accesses the linked frame and displayed it within the same window. A KMS database can be distributed across the network for collaborative work and sharing of information.

Editing Operations: Users can manipulate the content of a frame at any time. For example, in order to create a new link to a new frame, a user can move their mouse cursor over an unlinked item and click on the left mouse button to create a new frame linked from that item. When the user navigates away from a frame they have edited, their changes are automatically saved. Hence while the user is navigating, he or she also has access to the editing operations at the same time. In order to protect sensitive data from being modified, KMS implements protection status for the frame by allowing owner of the frame to decide whether the frame can be edited by other users.

Links and frames: In KMS, links are distinguished by the types of items they linked to: tree items and linked annotation items. Tree items are such as chapters of a book or procedures within a program. Linked annotation items point to materials such as comments and cross-references. Hence the link typing is based on the structural and associative relationships between items in KMS. Essentially the internal structure underneath these two types of links are the same.

The destination of a link is the whole frame in KMS and all links are one-way. Instead of multiple windows display, KMS displays two frames at the same time, each taking half of the screen. For the user's option, one frame can also be set to take up the whole screen, where in this case a current displayed frame is replaced by a new frame when users follow a link.

KMS has demonstrated that the fundamental design of a system's data model, which decides how frames and links are to be presented, will determine the look and feel of an interactive hypermedia system (Akscyn, Mccracken, and Yoder 1988).

2.3.3 Intermedia

Intermedia was developed at Brown University between 1985 and 1990. Unlike most earlier hypertext systems, Intermedia was modeled based on a multiuser hypermedia framework rather than a single hypermedia program (Haan, Kahn, Riley, Coombs, and Meyrowitz 1992). It is an educational hypertext system that allows authors to '*link information together, create paths through a corpus of related material, annotate existing texts, and create notes that point readers to either bibliographic data or the body of the referenced text*' (Yankelovich, Haan, Meyrowitz, and Drucker 1988).

Links and Nodes: Intermedia is a window-based system supporting shared and concurrent access to documents. Documents are displayed in resizable and scrollable windows. Users have three access rights to documents: read, write and annotate. These allow users to add new links to documents or to annotate documents.

Intermedia supports bi-directional links that ensure link consistency even in the case of a document deletion. All links are stored separately from the source text in databases, which made it possible to add new links without changing the original documents. A link destination can either be a whole node or part of the text within a document.

Intermedia is both a reader's tool and an author's tool where creation of new materials, making and following links are all integrated into a single seamless, multi-user environment. It consists of a suite of window-based applications which includes a text editor (InterText), a graphic editor (InterDraw), a picture viewer (InterPix), a three dimensional object viewer (InterSpect) and a time-line editor (InterVal). These applications share a common set of links which are maintained independently of each application. Intermedia has demonstrated the value of separating the link data from the document data and using a database management system to store and retrieve links.

2.3.4 Microcosm and DLS

Microcosm is an open hypermedia system which separates link management from content management and requires no markup on its content (Fountain, Hall, Heath, and Davis 1990). The initial work of Microcosm started with the Mountbatten archive where the development team was challenged with the archiving of a very large numbers of documents and links.

Links and Nodes: Microcosm actively supports the concept of external linking where links are treated as separate entities apart from the documents. Links are separated from the content and stored in linkbases. So when new documents are introduced into the system, they can immediately have links available. All users of the system including the author have the right to add links into their application. Users interact with the system by selecting data items (i.e. a string of text) and an action to perform on the items. Such actions include 'follow link', 'compute link', and 'show link'. Microcosm can incorporate third party applications (i.e. word processors or graphics viewers) by inserting links to them without requiring any mark-up on the content.

Microcosm supports cross-referencing of large scale information repositories through three types of links defined as :-

- *Specific links:* position-dependent links that are followed by selecting a specific location in the document.
- *Generic links:* defined by the existence of a link anchor (such as a word), can appear wherever the link anchors occur.
- *Dynamic links:* computed links which are dynamically generated, normally based on statistical or linguistic analysis on the content.

These link elements are stored in linkbases. This separation of links from the documents is useful because it is less expensive to modify the link elements as compared to changing the link resources. An insertion, deletion or modification of a link needs only be performed once in the linkbase and the update will be propagated to all the associated resources. Hence the crucial limitation of hypertext systems of requiring large effort in inserting links into documents is resolved. This highlights the core goal of Microcosm in reducing authoring effort.

Data Model: The core of Microcosm is a set of messaging protocols that enable the communication between its components (Lowe and Hall 1996). Messages that arouse from a user's selection are sent to the *link service* layer for link computation and dispatching of documents. Filters in the link service respond to these messages of link request (e.g. follow link, compute link and show link) with the appropriate actions where they can block the messages, ignore them, alter them or create a new one.

DLS: The ideas in Microcosm gave rise to the developement of the Distributed Link Service (DLS) (Carr, De Roure, Hall, and Hill 1995). DLS acts as a service component that allows databases of links to be published in order to provide hypermedia links for users in a hypermedia environment, particularly in the WWW. DLS was implemented as a proxy server that sits between the client and the web server. The proxy allows the creation, traversal and editing of links which are stored in the link databases. In addition to this, a variety of 'contextual' link databases are available which the user may select in order to get the best available link sets to suit their current information requirements.

The philosophy of Microcosm and DLS embodies the view that links are informational entities in their own right and they are managed separately from the data (Hall, Davis, and Hutchings 1996). The principle criteria in the design of both systems is to maintain a database of links and to apply these links to documents in any format. Hence a link does not belong to any document but is reusable across different datasets, which in turn can potentially lead to information overload when too many links appear on one page.

2.3.5 The World Wide Web

The invention of the WWW took place at CERN in the early nineties (Berners-Lee, Cailliau, Luotonen, Nielsen, and Secret 1994) . It was first developed to allow scientific data and ideas to be shared among people working at remote sites. The WWW later expanded and scaled rapidly across the Internet irrespective of boundaries, nations or disciplines. The WWW has emerged as the dominant hypertext technology and it becomes immensely popular due to the fact that it is highly accessible to anyone, anywhere in the world.

Data Model: The WWW uses the Hypertext Transfer Protocol (HTTP) to deliver text, graphics, video and audio across the Internet. The HTTP is a simple request-respond protocol that ensures objects requested are retrieved in rapid succession from widely dispersed servers. Each of these objects is identified by a unique URL (Universal Resource Locator) which serves as the object's address on the WWW. When users (clients) browse the WWW, they request an object by typing in a text string (searching) or following a link (browsing). The client's program will then retrieve the desired object from a 'server' which can be located locally or remotely.

HTML technology: The Hypertext Markup Language (HTML) is a markup language used for the authoring of documents on the WWW (Powell 1999). It consists of a collection of predefined tags or elements to describe the structure and format of a document. The conventional hyperlink on the web is implemented by HTML 'A' element where links are embedded in the documents and they are unidirectional. This simplicity of linking has seriously undermined the potential of the rich structure of links defined in the pre-Web hypertext community (Bieber, Vitali, Ashman, Balasubramanian, and Oinas-Kukkonen 1997; Davis 1999).

XML Technology: Extensible Markup Language (XML) is a universal standard for structured documents and data on the web (XML 1997). XML is a markup language much like HTML, but the difference is that XML is used to *describe* information whereas HTML is designed to *display* information. Unlike HTML which emphasizes on *how* to display the data, XML focuses more on *what* the data is. XML provides a mechanism for the developers to define their own tags to describe the content, e.g. <HEPATITIS>Negative</HEPATITIS> . Therefore, unlike the conventional HTML pages, XML documents are more structured, with meaningful labelling of content based on the author-defined tags. The 'how to display' aspect of the XML documents is addressed by Extensible Style-sheet Language (XSL) (Froumentin 2002). It is a language for expressing the presentation layout of the XML content.

XML Linking Language (XLink) is a recent technology that supports more complex linking on the web (DeRose 1999). According to the specification of XLink by W3C (DeRose, Maler, and Orchard 2001), XLink allows XML documents to:

- Assert linking relationships among more than two resources
- Associate metadata with a link
- Express links that reside in a location separate from the linked resources

XLink offers two types of links: extended links and simple links. Extended links offer full link functionality with complex structure, such as elements to specify local and remote resources as well as element that specifies arc traversal rules. Simple links involve only two participating resources and they offer less link functionality than extended links. An example of the link elements for an extended link are given below:-

- *locator:* remote resources that denote the link destination.
- *arc:* the traversal rule specifying the condition for the assertion of link.
- *title:* a title element containing a description of the link.
- *resources:* local resources that denote the link source.

XML linking not only allows connection to an entire node but also fine-grained anchors within the XML documents. This is made possible by XML Pointer Language (XPointer) (DeRose, Daniel, Grosso, Maler, Marsh, and Walsh 2002). For example, an XPointer could be used to address the string 'arthritis' in all citations in an XML file. XPointer is based on the XML Path Language (XPath) (Clark and DeRose 1999) where it supports addressing into the internal structure of XML documents. This offers more consistency as compared to the use of character offset (e.g. Microcosm) which can be upset when the content is changed.

The WWW has gained high popularity within the user community due to its simplicity in usage and its widely distributed nature. With the arrival of XML and its link functionality, there seems to be a promising future for the WWW to evolve into a more powerful hypertext system. Still, all these new specifications and web standards are yet to be fully implemented in order to reveal the full potential of the WWW.

2.4 Summary

This chapter has provided a background of the research in hypermedia and explained the concepts of nodes and links that are fundamental to the work in this thesis. Hypermedia first evolved from Vannevar Bush's concept of MEMEX and it was later coined as hypertext by Ted Nelson in his Xanadu project. The concept of hypermedia was defined as a corpus of information space supported by its navigation and browsing facilities. Nodes and links are the essence of hypermedia where a node encapsulates an information entity and is connected to other nodes through the mechanism provided by links. Five examples of hypermedia systems were discussed towards the end of the chapter. This chapter has provided readers with the background of hypermedia, and the subject will be discussed further in the next chapter with emphasis on the use of hypermedia in the context of education.

Chapter 3

The Role of Hypermedia in Education

Chapter 2 introduces the origin of hypermedia and has offered a fundamental perspective of hypermedia in the context of nodes and links. This chapter discusses the role of hypermedia as a dominant force in educational technology. The chapter begins with discussions on various learning technologies and theories that are influential towards contemporary hypermedia learning environments. Section 3.1 discusses the differences in approach between Intelligent Tutoring Systems (ITS) and hypermedia in teaching and learning. This is followed by section 3.2 which focuses on the effect of browsing behaviour on learning. Section 3.3 explains the theory of situated learning and describes how it can be simulated in a hypermedia environment for more engaging learning. The chapter ends with a few examples of hypermedia systems to demonstrate the use of hypermedia in education.

3.1 Intelligent tutoring system vs hypermedia learning

ITSs have great influence in hypermedia learning, particularly in the earlier educational adaptive hypermedia systems (e.g. ELM-ART (Brusilovsky, Schwarz, and Weber 1996)). ITSs incorporate Artificial Intelligence (AI) techniques in computer programs to provide virtual tutors that know what to teach, who they teach and how to teach (Nwana 1990). ITS and hypermedia have essentially started off in two opposite directions: the ITS focuses on the aspect of problem solving in the learning continuum; whereas hypermedia focuses on providing a facility for navigations within learning materials in an essentially non-pedagogical environment. Hence ITS is a computer-driven tutoring system whereas hypermedia is a student-driven, free exploratory learning environment (Brusilovsky 2001b). Earlier adaptive hypermedia systems such as ELM-ART are inspired by ITSs as they exploit the synergy between the intelligence components of ITSs and the free-exploratory basis of the hypermedia.

3.1.1 Intelligent Tutoring Systems

ITSs have an intelligence component which is not normally found in a hypermedia system. This intelligence component is responsible for establishing the teaching sequences of learning materials and provide detailed diagnostic of errors and answers for questions posed by the students (Murray 1999; Sleeman and Brown 1982). One of the main goal of ITSs is to support one-to-one tutoring and to provide direct response according to the need of the students.

Besides the tutoring component, ITS is also equipped with the student model module and the expert knowledge module. The student model is the dynamic representation of the knowledge and skills of the student (Ross and Millington 1987; Self 1974; Sleeman 1985) whereas the expert knowledge module comprises facts and rules of the particular domain to be conveyed to the students (Nwana 1990; Mandl and Lesgold 1988). To date, ITS has been used across many different domains and some of the examples are highlighted in Table 3.1.

Examples of ITS	Domain	Descriptions
ACE (Sleeman 1975)	Nuclear magnetic resonance spectra interpretation	a supportive environment for students to solve non-deterministic tasks
LISP Tutor (Anderson and Reiser 1985)	Lisp programming	problem solving guide to incorrect production rules
GUIDON (Clancey 1983)	Medical diagnosis	suggests treatment for bacteria infections
SOPHIE (Brown, Burton, and Bell 1975)	Electronic troubleshooting	on-the-job consultant to provide troubleshooting strategies on electronics devices
SCHOLAR (Carbonell 1970)	Advising and help system	handles unanticipated student questions and generates instructional materials
WEST (Burton and Brown 1982)	Game	simulates board game, monitors and evaluates the student's moves

TABLE 3.1: Examples of ITS in different domain

Sleeman and Brown (1982) have pointed out that it is often conflicting to incorporate the tutoring component within the 'discovery learning' environment because, in order to 'tutor' well, the system sometime has to constrain the student's instructional path. Hence ITSs can lose the advantage of free-exploratory learning which promises deeper learning through learners' self-discovery of their own links within the information space (Becker and Dwyer 1994).

3.1.2 Hypermedia-based Learning

The essence of hypermedia is that the users are free to follow links wherever they are please and they have complete control over the learning activities. Hypermedia creates an environment that allows the opportunity of learning by exploration (Mayes, Kibby, and Anderson 1990; Hammond 1993).

The 'basic' hypertext as termed by Hammond (1993) serves solely as a mechanism for delivering information. It presents a linked network display of information where the students are left completely their own devices to explore. The more 'sophisticated' hypertext systems provide navigation facilities such as overview maps and search mechanisms to aid learners through their learning materials. They also incorporate learning support activities such as problem solving and quizzes to aid learning. Its potential in education spurs a different role for hypermedia systems apart from information delivery.

Hammond summarises three different dimensions along which hypertext-based and computer-based learning systems vary: learner control, engagement and synthesis, as shown in Figure 3.1. In this figure the basic hypertext systems are located in the lower back left region where they typically allow full learner control, provide passive engagement and only present materials to learners. More advanced hypertext systems tend to move along the different dimensions to present a learning environment that requires more active engagement and creativity from the learners.

The level of learner control within hypertext systems varies from one system to another. If too much freedom is given, users are at the risk of inefficient browsing, as pointed out by Gay (1986), hypermedia systems that give multiplicity of choice but the minimum of guidance may not be ideal for learning. Hammond suggested the inclusion of more explicit direction and control in the hypertext systems to restrict the learner to realistic goals and sensible part of the domain knowledge. However, the direction and control need to be mixed with the provision of freedom of action to the learners. This is realised by the availability of navigation tools within the hypertext environment such as maps, indexes and overviews to help learners define their goals and actions, without hampering their freedom of choice.

The second dimension, engagement, refers to the extent the learner is required to process the learning materials either actively or passively (Hammond 1993). Craik and Lockhart (1972) pointed out that the more the learners think about the material in depth and variety, the better they will remember it. This is why active engagement in learning materials is so important. An experiment done by Cohen (1984) has illustrated that learning-by-doing contributes to higher recall rate of materials. Hence in hypertext, instead of leaving learners only to cursory browsing which results in shallow processing and poor retention of knowledge, learners can be engaged in task and goal oriented activities such as interactive demonstrations, simulations and self-assessment (Hammond

1993).

The dimension of synthesis refers to the nature of the learning activities, where it requires learners to create materials or relationships rather than merely to observe them (Hammond 1993). Synthesis is dependent on the degree of engagement as described above since creative learning generally requires substantial level of engagement from the learners. Examples of creative learning activities in hypertext, as summarised by Hammond, include re-working of learning materials (e.g. creating multimedia essays), specification of learning sequence (e.g. self-generated tours), use of annotation facilities and manipulation of structural overview.

Hypertext supports a learning approach which is based on learner's exploration and choice. It is also a platform for designers to deploy different tools and techniques to obtain educational attainment. It is a challenge to hypertext designers to achieve the right balance between learner and system control, to decide on the extent of learner's engagement and the nature of learning activities in order to achieve effective hypertext-based learning.

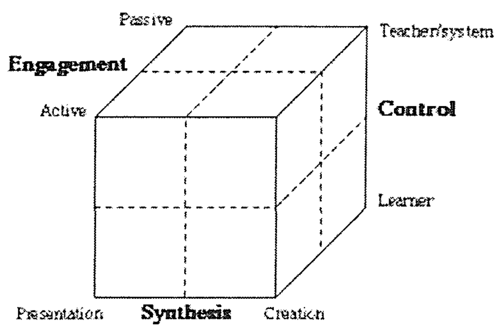


FIGURE 3.1: The cube height, depth and width representing degree of learner control, engagement and synthesis in hypertext-based learning, as described by Hammond (1993)

3.2 Learning-by-browsing

Morse (1973) describes browsing as an activity of seeking new information where the information sought is not known but anticipated. The process involves an element of randomness, parallel to a person roaming among the library shelves (Hildreth 1982). Hildreth (1982) suggests that '*browsing is a purposeful activity occasioned by a felt of information need or interest*'. This purposeful yet non-specific process is exploratory-based where users search for information without creating boundaries within which to concentrate their effort on (Batley 1989), and it is driven by the users' interest and need, depicting that the learner is in control. In hypertext, browsing is facilitated by the structure of information that is pre-arranged in such a way that exploration can take place (Oddy 1977; Hildreth 1982). Browsing in hypertext involves following an idea using the linking mechanism of the hypertext element.

Resources in an information-rich hypermedia environment allow users to browse the material in an informal way until something of interest commands greater attention. Alternatively, they may search the material in a goal directed manner to find the information they needed. The former is analogous to an informal learning environment (Duchastel 1989) where one's attention skims a wide range of information. However, a corpus of information in a hypermedia environment is not necessarily an ideal learning environment as it is essentially 'non-pedagogical', and generally provides minimal structural support (Duchastel 1991). On the other hand, this mode of learning is only effective if the reader already has a fairly well developed *schema* for the material. A schema (Anderson 1994) is a bank of relevant prior knowledge that is activated before or during the reading and it is updated after the reading. Readers use their schema, which is their prior knowledge, to make new connections with new information. In parallel to browsing in hypertext, users also use what they have already known to determine the next piece of information to be accessed, hence modeling the accretion process in learning (Rumelhart and Norman 1978). For a well-developed schema, even by paying only scant attention to the material as often happens during browsing, it is often sufficient to modify a schema, and hence learn. Practitioners, or those that are knowledgeable in a field therefore, may use this technique in a casual manner and are able to informally upgrade their knowledge of a subject. Novices on the other hand, with less well-developed schemas, are more easily overwhelmed and quickly suffer from cognitive overload.

In view of these variations in users' schema, a hypermedia application can be made to be adaptive in order to tailor its information and guidance to users of different level of knowledge within the informal learning environment.

3.3 Supporting situated learning in hypermedia

Teaching in the abstract (not in the context where a problem is situated), often results in 'inert knowledge'. This inert knowledge, coined by Whitehead (1929), is knowledge that can only be used in school exams and often not available when required to solve a problem. This type of knowledge is gained through memorization or theory reading, it is unable to be applied in any useful manner.

The theory of situated learning promotes the acquisition of knowledge in a meaningful context (Brown, Collins, and Duguid 1989; Herrington and Oliver 1995). In the situated mode of learning, students are put through authentic life experience where knowledge gained is embedded in a social or physical context. The theory suggests that learning through real life experiences produces more usable and robust knowledge (Brown, Collins, and Duguid 1989) as compared to inert knowledge. In recent research, this situated learning approach began to be adopted as a model of instruction in computer based learning environments (Bransford, Sheerwood, Hasselbring, Kinzer, and Williams 1990). In supporting this situated learning approach, hypermedia is capable of presenting engaging interactions with the students and at the same time provide a database of information to support learning (Harley 1993; Reeves 1993). Hypermedia can be used to provide an alternative to the real life settings by enriching the learning experience through the availability of graphics, videos, audio and text simulation.

3.4 Examples of Educational Hypermedia Systems

The previous sections have encompassed the nature of hypermedia-based learning which promotes free-exploratory based learning and control by learner. The aspect of learning-by-browsing and situated learning are briefly mentioned and they are influential towards the implementation of JointZone in this thesis. JointZone provides multiple navigation supports and adaptive features to aid browsing in the free-exploratory environment (see Chapter 6). The implementation of case studies in JointZone (see Section 4.3) was an attempt to promote situated learning in the hypermedia environment.

The following section shows a few examples of educational-based applications that have been developed in the hypermedia environment. The focus is on how different learning technologies have been integrated into this environment to demonstrate the potential of hypermedia in the learning paradigm.

3.4.1 Hitch-Hiker's Guide

The Hitch-Hiker's Guide is a Learning Support Environment (LSE) that facilitates the learners' exploration of informal knowledge domains. In this environment learners can benefit from the flexibility of accessing materials in hypertext by gaining control over the sequencing of learning materials to meet their individual learning strategy (Allinson and Hammond 1989).

The authoring component in the systems allows teachers to produce a network of display frames, multiple-choice quizzes, interaction demonstrations and experiments. There are a variety of navigational tools which include guided tour to aid initial use of the system, maps that permit students to see where they are in relation to other display frames and indexes which allow direct access to keyword-coded frames. The system was implemented on a network of microcomputers connected to a hard-disc based file server.

Evaluation of this system has shown the need to provide a variety of navigational tools to facilitate learning. It was observed that as learners gained familiarity with the system, they preferred to be in control, as shown by their navigation patterns which changed from system control (i.e. tours) through shared control (i.e. maps) to user control (i.e. links).

3.4.2 StrathTutor

StrathTutor is a hypertext system designed for tutoring applications (Kibby and Mayes 1989). Links are not explicitly represented but computed at run time based on where the reader is and where they have been before. This dynamic generation of links was based on a routing algorithm that was modelled after the human memory. Links are computed based on a heuristic pattern matching which selects the closest set of frames.

StrathTutor offers complete learner control where the progress through learning materials is entirely a matter of choice by the learner. Unlike traditional hypertext which presents users with a fixed set of links between the nodes, StrathTutor requires users to explore using links that are being dynamically presented. Learners need to constantly map the information being discovered with those that they have already looked at. According to (Rumelhart and Norman 1978), this process of inserting information into an already developed conceptual framework is a crucial stage of learning.

StrathTutor has exhibited an important aspect of learning-by-browsing in a 'dynamic' hypertext. However one of the shortcomings of this system is users can become lost in the information space. In addition to this, as the hypertext system expands to include more nodes, the complexity of dynamically generating links between the nodes will potentially become a serious problem.

3.4.3 Atlas

Atlas was developed by Garlatti and Sharples (1998) to provide a computerised brain atlas in support of radiology training. In radiology practice, atlases are used as brain maps in anatomical structure visualisation, diagnosis and surgery planning. Brain maps offer both 2D and 3D views of brain structure in different perspectives such as neuroanatomy, cerebral function and blood flow. These images are combined with text through hypermedia links that connect areas in the images to descriptive text.

The computerised atlas consists of a brain map, a database of domain knowledge, imaging tools with procedures for segmenting the brain images, and a knowledge base system which acts as a decision model to support medical tasks. All these components are linked together through a hypermedia interface to support information search and retrieval. The user interacts with the system via a hypermedia tool that offers the flexibility of access and support . This tool manages the information retrieval of cases, slices, texts, drawings and stored domain knowledge, and it invokes computation tools such as visualisation algorithm and problem solving methods.

Atlas not only offers a support environment for browsing and searching through libraries of case images and textual information, but also an active environment to aid problem solving. Atlas has a decision support system that is supplemented by a user model to generate intelligent help and context-specific advice. The Atlas project has expressed the need to expand the existing knowledge base and the possibility of adopting an adaptive mechanism to tailor its vast amount of information according to users' interests and needs.

3.4.4 SCALPEL

SCALPEL, which stands for Southampton Computer Assisted Learning Pathology Education Laboratory is a courseware developed at the University of Southampton to replace the traditional pathology laboratory teaching (Kemp 2000; Kemp, Davis, Roche, and Hall 2002). It was implemented in a hypertext environment using Microcosm (see section 2.3.4).

The content of SCALPEL was identical with the materials previously delivered in the traditional laboratory. It is in the format of case-based reasoning which includes a variety of media types such as text, images, video, simulation and animation. SCALPEL was equipped with a multiple choice question engine to provide case-based questions and immediate feedback to students' answers. Students can make full use of hypertext links to access supplementary domain materials while attempting the case-based questions in the Microcosm environment.

An empirical study of this work which spanned over three years has shown that there was no change in the effectiveness of student learning when the pathology practicals were delivered either in the laboratory or SCALPEL. The students' feedback voiced out a few suggestions to improve the learning environment, which include glossary terms, online textbooks, ability to ask questions online and get answers, online Notepad, optional extra practicals, more links to background materials, more animations, and sound clips to introduce sections such as patient histories. The study has also shown that there was a great preference among the students to consult a tutor concerning the pathology content of the practicals. SCALPEL resolved this by replacing the tutor with a relatively simple software agent to provide limited dialogue via an 'Answer Garden', where in this approach students pose questions, and answers to these questions (provided in due course by the domain expert) are collected for future sharing with other students. SCALPEL also made use of the Microcosm links to show background materials, such as glossary terms for immediate feedback. The improvement in the acceptance of SCALPEL in subsequent years was confirmed by a decreasing needs among the students to consult tutors.

3.5 Discussion

These series of hypermedia systems developed for teaching and learning have demonstrated the importance of hypermedia in education as well as highlighting the many roles it can play. The different features in each system has provided new insights into the capability of hypermedia in delivering a learning environment. Almost all of the systems took advantage of the flexible nature of hypermedia to promote self-exploratory learning and offer learner control in the learning process. A question remains, how do we build on this free-exploratory learning environment to achieve its full potential to bring about effective learning? The Hitch-Hiker's Guide suggested the provision of a variety of navigational tools to facilitate learning. Atlas includes an active problem solving environment and SCALPEL provides a simple questions and answers portal. Hypermedia has great potential in serving as a platform for the incorporation of various learning techniques and supporting tools to create more effective learning environments and this continues to pose as a challenge to both hypermedia designers and education experts.

3.6 Summary

Hypermedia systems support a rich environment for discovery purpose and this promotes a self-exploratory learning environment where learners are in control of the learning process. Unlike computer-assisted learning systems, such as intelligent tutoring systems, that focus on the aspect of problem solving in the learning continuum, hypermedia focuses on providing a facility to navigate between learning materials in an essentially non-pedagogical environment. Hypertext-based browsing can be viewed as a form of *informal learning* where it is driven by the user's interest and involvement. Hypermedia system also serves as a platform for the application of situated learning theory to promote a contextual learning environment through the simulation of real life setting.

Various examples of hypertext learning systems have shown us the potential of hypermedia for incorporation of various techniques and tools to facilitate learning in the paradigm of educational technology.

This chapter has given its readers a general overview of the use of hypermedia in the education field. The next chapter will discuss the implementation of a web-based medical application that is central to the work in this thesis.

Chapter 4

Implementation of JointZone

This chapter documents the development of JointZone as a web-based medical learning application, before the integration of any adaptive elements. Firstly, the implementation structure of JointZone is laid out and the core components of its architecture are identified. Next, the implementation of case studies will be discussed. Then the linking approach, based on different link types will be highlighted. This chapter will conclude with a usability study to assess the application's basic functionality before the adaptive features are integrated.

4.1 Project Description

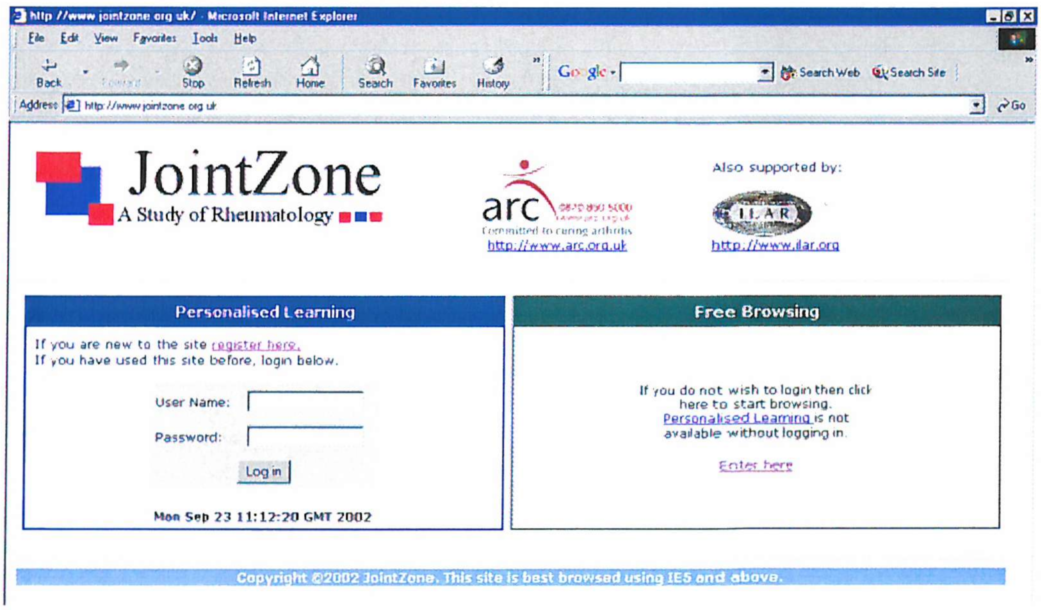


FIGURE 4.1: A screen shot of the JointZone website

JointZone is a web-based medical learning application developed primarily for university medical undergraduates (Figure 4.1) (Ng, Armstrong, Hall, and Maier 2002; Armstrong, Ng, Maier, and Hall 2002). The domain is in rheumatology which deals with the study and treatment of rheumatic diseases. The project was a collaborative effort that involved a medical expert who had generated the contents, an educational developer who had tackled the pedagogical issues of the website and the author who had implemented the application based on the developer's perspective.

The content of JointZone exists in two types: declarative knowledge (e.g. medical theory) and procedural knowledge (e.g. how to approach clinical problems). The previous exists in the form of an 'online electronic textbook' which encapsulates a rich source of materials under the subheadings of basic science, rheumatic disorders, approach to patient, investigation and disease management (see Figure 4.2). The nodes in JointZone are populated by documents which come in varying page length. Each document details a topic under a subheading. The documents are illustrated with photo images taken on various forms of rheumatic diseases. There are also videos that captured the clinical examinations on patients. This network of information can be browsed by selecting sections from the side menu bars to reveal documents or using a search engine to look up specific information. Integral to this information network is the linking approach (see 4.4) that bind related documents and references through three defined link types. The procedural knowledge is delivered through a total of 30 interactive case studies. The 'virtual patients' in the case studies present rheumatic disorders set in a variety of clinical scenarios, most of which arise frequently in typical district general hospital rheumatology clinics. The overall aim of this project was the integration of adaptive features in a fully functional website to present a personalized web-based learning experience.

4.2 Implementation

JointZone is implemented in a web-based environment, built using the Java Server Pages (JSP) platform (Fields and Kolb 2000). The content of the website is structured using XML. The display of the pages are implemented using XSL. IBM's DB2 was used as the database to store links and user information, taking full advantage of the built-in search and retrieval mechanisms.

JSP offers the facility to generate dynamic web content, a fundamental element in building adaptive hypermedia applications. JSP allows Java programming code to be embedded into the web pages to describe how content is to be manipulated. JSP also provides the mechanism of *session tracking* to identify individual users across multiple HTTP requests. Session tracking is conveniently incorporated in the session management component of JSP and is transparent to the web developer. The session management maintains a state or identity of a user through the idea that all of the user's request for web pages during a given period of time are

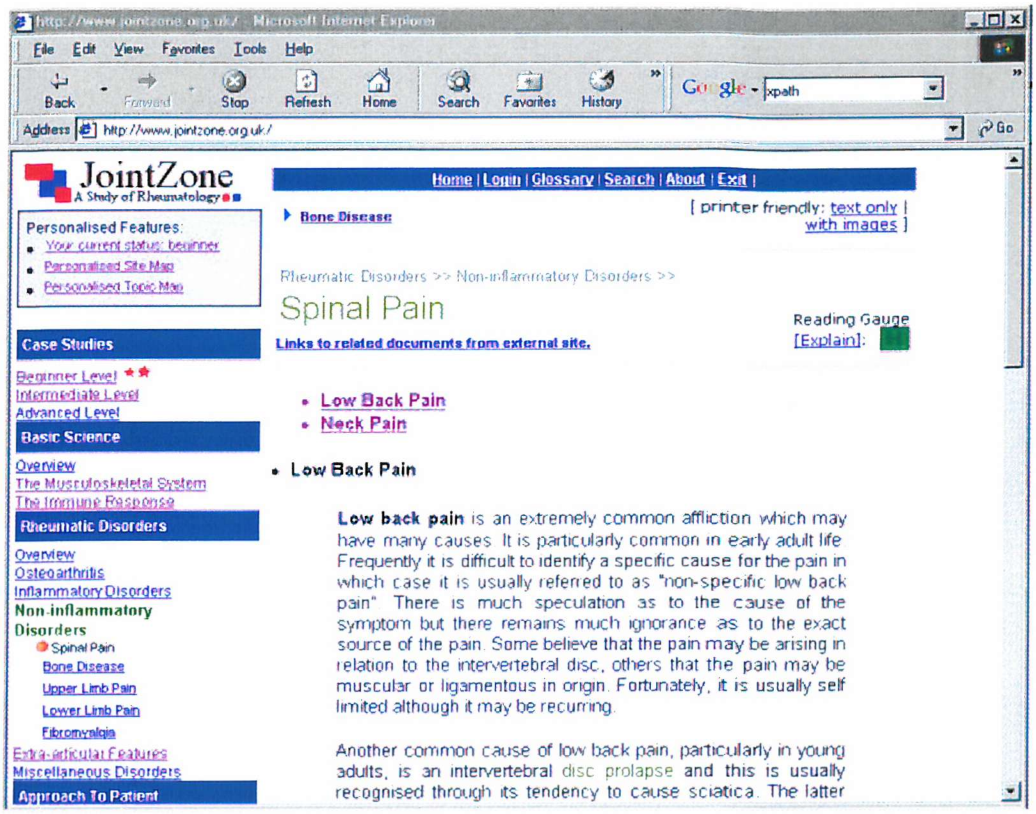


FIGURE 4.2: The layout of a document in JointZone, the side menu reveals the structure of the site

included in a *session*. This process makes up for the inadequacy of the HTTP stateless protocol by establishing a unique session for each individual user during a client-server interaction, this in turn becomes an essential mechanism for user modeling. On the client side, a session starts with the loading of a web browser and normally ends with the closing of the browser, unless intentionally disconnected by an external program. In JointZone, a login procedure is established to allow information from a session to be stored in the database. However, the website can still be accessed without login, in which case the session will be labelled as 'anonymous' and any data accumulated in this session is lost when the session is discontinued.

XML-based content in JointZone is *well-formed* (a well-formed document follows the rule that every tag must have a corresponding end tag) but not *validated* according to the rules of Document Type Definition (DTD) (DTD defines the type of content and is used to ensure documents are valid). The motivation behind this was that XML was only be used in the structuring and labelling of the content in order to provide a basis for adaptation. Hence the validation rules were not adhered for two reasons: firstly, this process delays the page loading time and secondly, validated documents are mainly used for data sharing (e.g. in link databases), which is not the case for most documents in JointZone.

4.2.1 The System Architecture

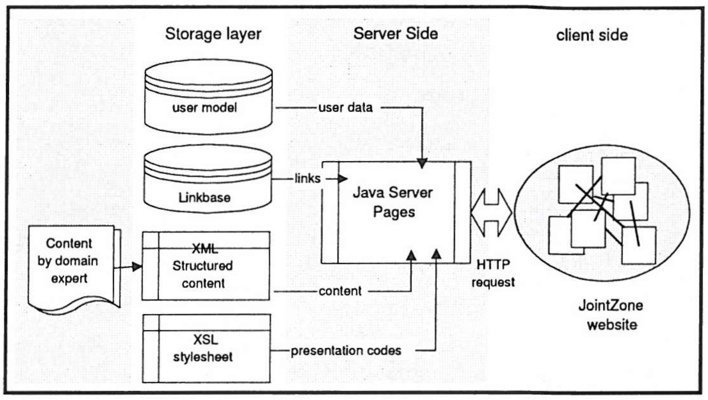


FIGURE 4.3: The system architecture of JointZone

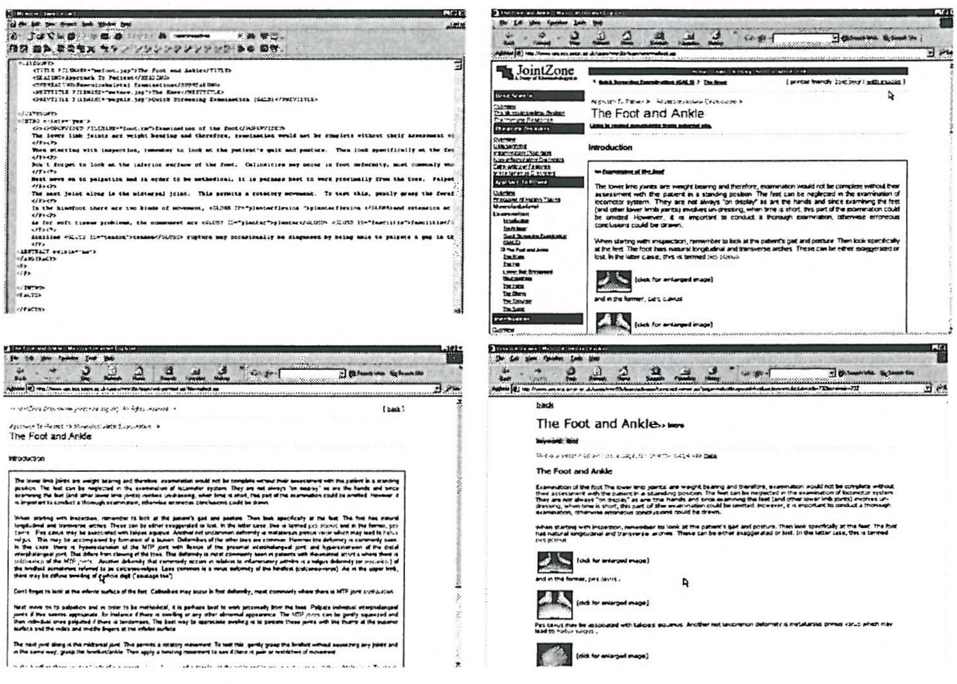


FIGURE 4.4: An example of an XML document (top left) displayed in 3 different styles: original version (top right), print version (bottom left) and search result display version (bottom right)

The system architecture as shown in Figure 4.3 presents a view of *'separation of data and information'* as described in ((Lowe and Hall 1996), p67). Content provided by the domain expert is structured using XML which is in turn rendered by the web browser based on the XSL stylesheet. This process allows presentation code to be separated from content and encourages information re-use. For example, the same XSL style sheet can be used to display multiple XML pages. Likewise, only one copy of the XML content is maintained even if it is presented in different ways in the browser (Figure 4.4). Links are stored separately from the content in the linkbases, which are implemented in either DB2 or XML flat files. All users' information provided for adaptive purposes are stored in DB2.

The JSP acts as a shell to include the XML content, XSL presentation codes and Java codes before the web pages are presented to the users. The JSP pages also connect with the database through the JDBC driver[1] to pull in links or user information during an adaptive decision making.

4.3 The Interactive Case Studies

The benefits of situated learning (see section 3.3) prompted the integration of interactive case studies to simulate the clinical diagnosis process of a Rheumatologist. A case study approach was adopted for JointZone as it can holistically represent the complexity of clinical reasoning. Students are then able to develop their procedural knowledge, which elaborates how doctors approach problems, interpret clinical information and make decisions (DesCoteaux and Harasym 1998). According to Nkanginieme (1997), a physician needs to possess the cognitive skill to:

- obtain and recognise symptoms in the patient
- identify appropriate system involved
- speculate on the pathological processes
- differentiate pathological processes
- identify possible causes of pathology
- evaluate all pieces of information and make a clinical diagnosis

This list of cognitive skills are encapsulated within the explicit procedural steps in the case studies which includes (Ng, Maier, Armstrong, and Hall 2002):

- *referral letter*: reading a letter from the patient's general practitioner.
- *patient history*: taking down medical history through a series of questions.
- *examination*: examining the patient by clicking on the body parts or systems on the screen.
- *investigations*: requesting investigations on the patient by selecting from a range of options, such as haematology, immunology, microbiology etc

[1]an API that provides cross-DBMS connectivity to a wide range of SQL databases

- *diagnosis*: making diagnosis by answering a multiple-choice question. Feedback from the system is given at this stage according to the student's selections in previous stages.
- *clinical management*: reading a general conclusion on the clinical management of the current case study.

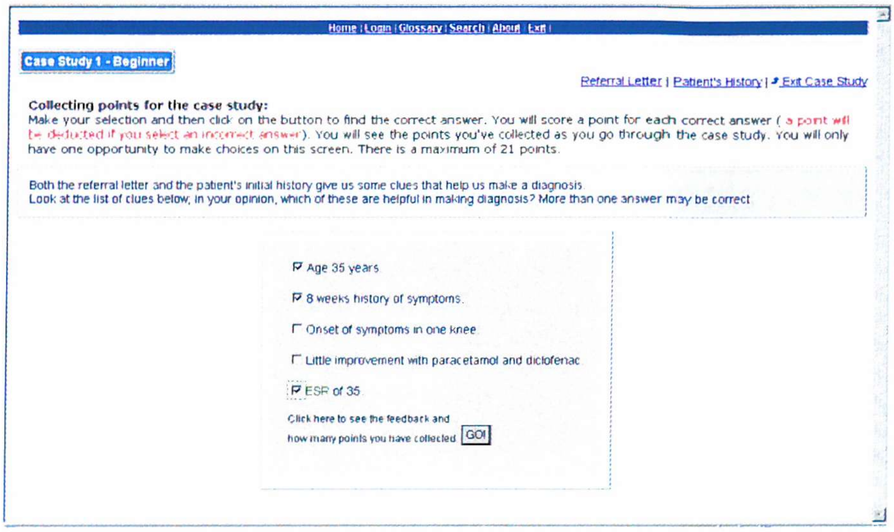


FIGURE 4.5: Beginner level of case study: In this level users are asked to recognise the value of particular pieces of clinical information, identify pertinent investigations and make a diagnosis.

FIGURE 4.6: Beginner level case study: subsequent feedback (such as indication for 'correct', 'wrong', 'not selected correct' answers and detail explanations) is given for the previous selection as shown in Figure 4.5

The procedures above mimic the decision making processes in a clinical scenerio. This is an attempt to expose the students to real clinical scenerios and help them to achieve

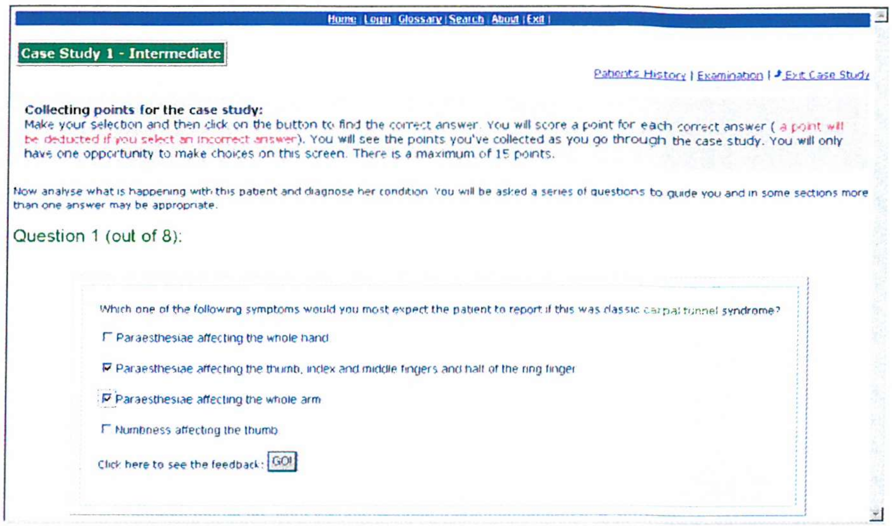


FIGURE 4.7: Intermediate level case study: students are asked to reassess a case in which the original diagnosis is under question

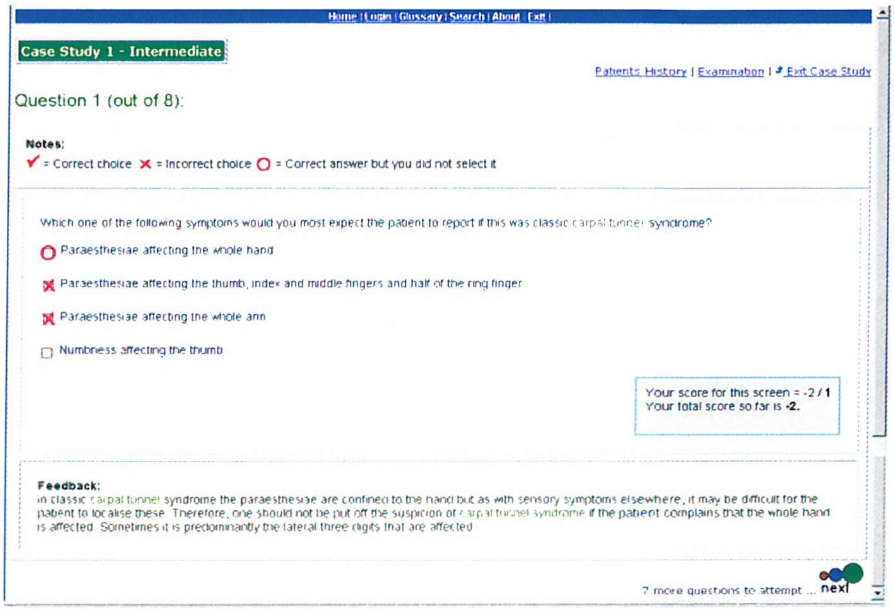


FIGURE 4.8: Intermediate level case study: subsequent feedback is given for the previous user selections as shown in Figure 4.7

the objectives that are prelisted by the domain expert. These objectives are unique to each case study. For example, in one particular case study, its objectives are to:

- recognise the importance of clinical features in distinguishing between inflammatory and non-inflammatory disorders.
- recognise the value of extra-articular clinical features in diagnosing rheumatic disorders.

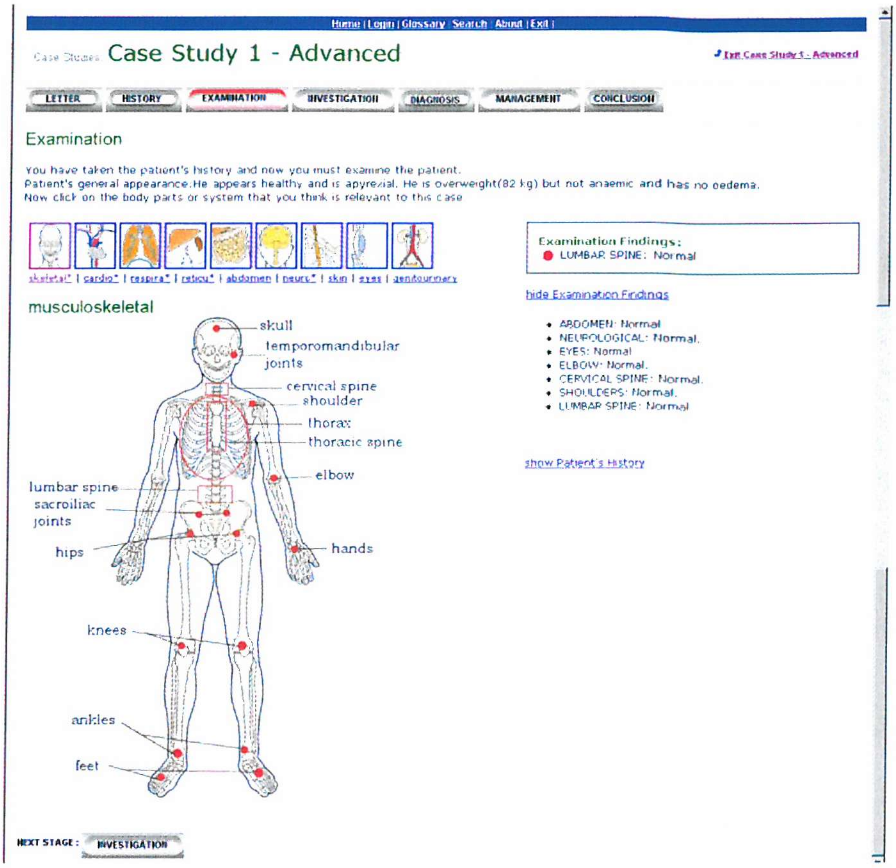


FIGURE 4.9: Advance level case study (Examination stage): students are given a wide range of diagnosis options for each stage. They have to progress through a series of stages: the referral letter, patient history, the examination, investigations, diagnosis and clinical management.

- evaluate information gained from the history and physical examination and provide a preliminary diagnosis.

To avoid overloading novices with too much complication, all case studies are graded into three levels:

- *beginner level*: the goal of this level of case studies is to help users recognise the value of particular pieces of clinical information, identify pertinent investigations and make a diagnosis. (Figure 4.5, Figure 4.6)
- *intermediate level*: the goal here is to reassess a case in which the original diagnosis is under question. (Figure 4.7, Figure 4.8)
- *advanced level*: the goal is to test the student's ability to differentiate key information from a wide range of diagnosis options. (Figure 4.9, Figure 4.10)

The interactive process in the case studies are two ways where the system captures actions performed by the users, such as selecting a diagnosis and the system also provides

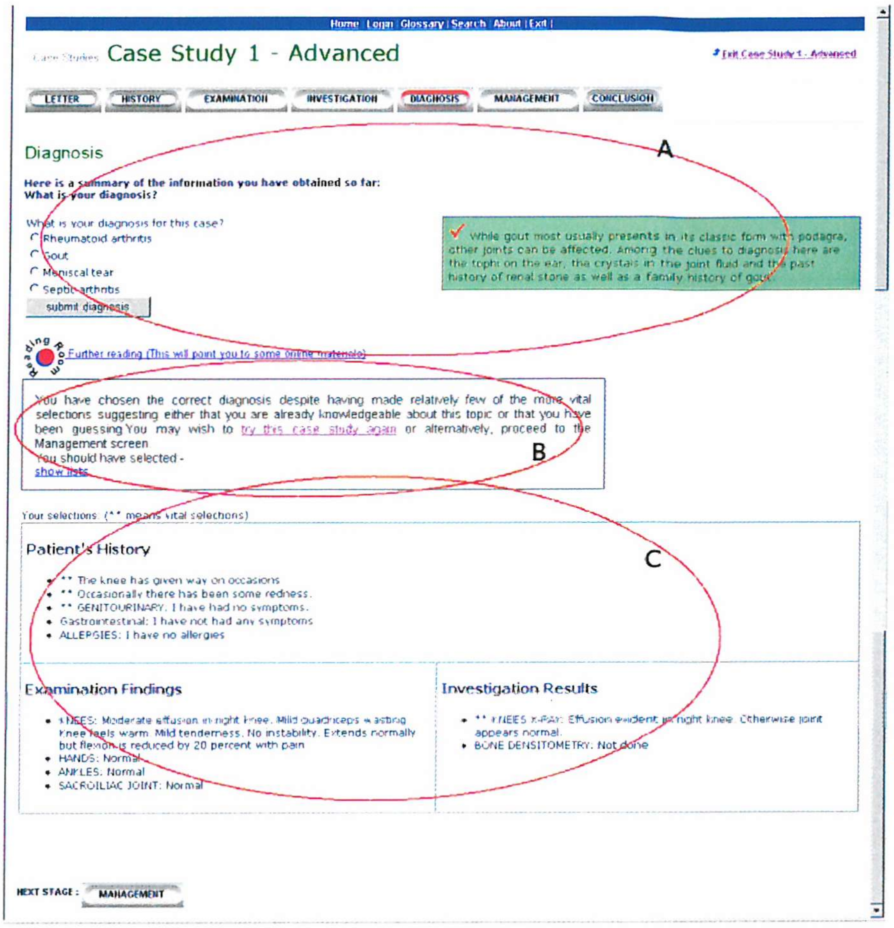


FIGURE 4.10: Advance Level Case Study (Diagnosis stage): (A) From a list of possible diagnoses, students select their preference based on their interpretation of clinical information gathered. (B) They then obtain subsequent feedback on why that diagnosis is likely to be appropriate. (C) The clinical observations that students have gathered by working through the case study are recorded so they have ongoing access to this information as they proceed. At the diagnostic stage, students are given a complete record of the examination findings and investigations. If the system feels insufficient or inappropriate information has been gathered this will be pointed out to the student.

subsequent feedback based on the users' selections.

This is implemented using JavaBeans(TM) technology[2], which is a reusable java based software component that is platform-independent. A Java bean is used to construct the online marking mechanism to provide instant feedback to the students action (for code details see Appendix A: Table A.1, Table A.2).

[2]http://java.sun.com/products/javabeans/

4.4 Link Generation in JointZone

In JointZone, three types of links were implemented, namely the structural links, the referential links and the associative links (Lowe and Hall 1996):-

- structural links: for organising the structure of the website,
- referential links: for linking keywords with their definitions,
- associative links: for relating pages of the same context together.

4.4.1 Structural Links

Structural links define the structural layout of a domain, they ensure the ease of navigation and usability within an information space. Examples of structural links are the table of contents, link menus, 'next' and 'previous' links, and jump links which provide shortcuts to fragments within the same page (see Figure 4.11).

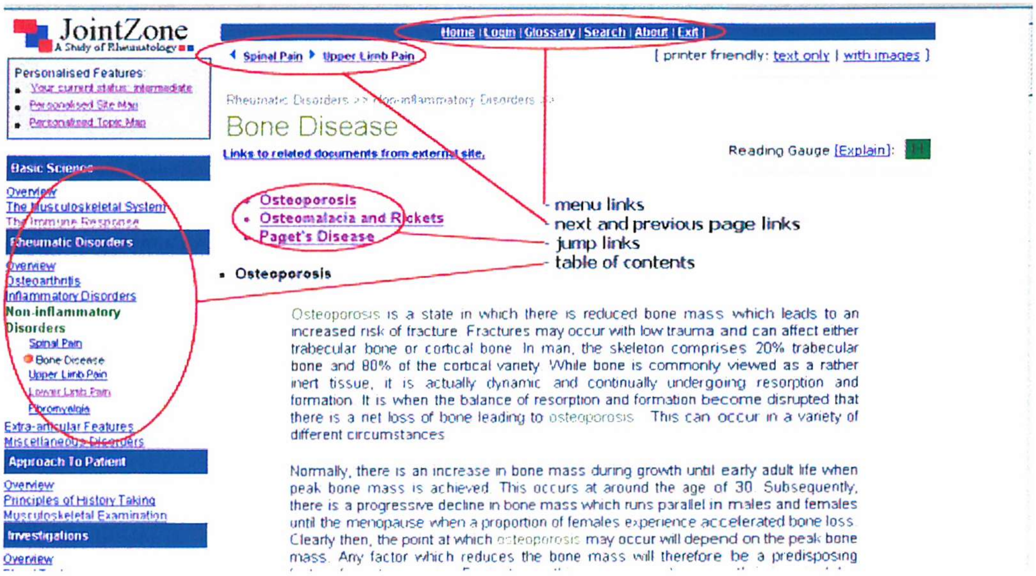


FIGURE 4.11: Structural links in JointZone, for example the menu, table of contents, next and previous page links and jump links within a page

4.4.1.1 Implementation of Structural Links

Simple links (section 2.2.2) were used to construct the structural links in JointZone. These links were built manually using the standard HTML linking mechanism and were therefore embedded in the documents. Any changes to the links had to be done manually by the author. However the authoring effort was reduced through the use of XSL (see section 4.2), where every document shares a common style that describes the presentation of content and renders the display of links. An XSL *Transformation* method called XSLT was used to manipulate the generation of the same structural links in different documents. For example in Table 4.1, the 'next page' link is only generated if a particular document has a sibling page within the site layout structure.

```
<xsl:comment> if this page has a sibling page </xsl:comment>
<xsl:comment> generate next page link        </xsl:comment>
<xsl:if test="DOCUMENT/CATEGORY/NEXTTITLE[@FILENAME[.=.]]">
    <xsl:comment> this is HTML links </xsl:comment>
    <A class="innerlink" title="NEXT PAGE">
        <xsl:attribute name="href">../xml/
            <xsl:value-of select="DOCUMENT/CATEGORY/NEXTTITLE/@FILENAME"/>
        </xsl:attribute>
    </A>
</xsl:if>
```

TABLE 4.1: The use of XSLT to manipulate the display of structural links. In this case the 'next page' link is only displayed if this document has a subsequent sibling page in the site layout structure.

4.4.2 Referential Links

Referential links in JointZone are essentially the glossary links that relate a word in context to its definition. They are not the typical compilation of glossary indices that appear in a single glossary page but these links can be followed directly from any pages in the domain, anywhere in a page where a glossary word exists (Figure 4.12). From a learning perspective, the glossary links are useful to learners to conveniently fill in their missing prerequisite knowledge without leaving the current document. The explanation of a term can be given at any time simply by following the glossary links.

4.4.2.1 Implementation of Referential Links

The generation of referential links in JointZone was very much influenced by the generic linking mechanism in Microcosm. A generic link can appear randomly in any document where the word or phrase that is the source anchor of the link exists. But there was a difference in terms of implementation from Microcosm; the link pointers of referential links in JointZone were embedded in the documents with the link destinations stored in a linkbase.

In generating these glossary links, all the pages in XML format are parsed through an offline pre-processor to insert the XML mark-up tags for each glossary word. The reason for doing this offline is to avoid a long delay to the page loading time during a browsing

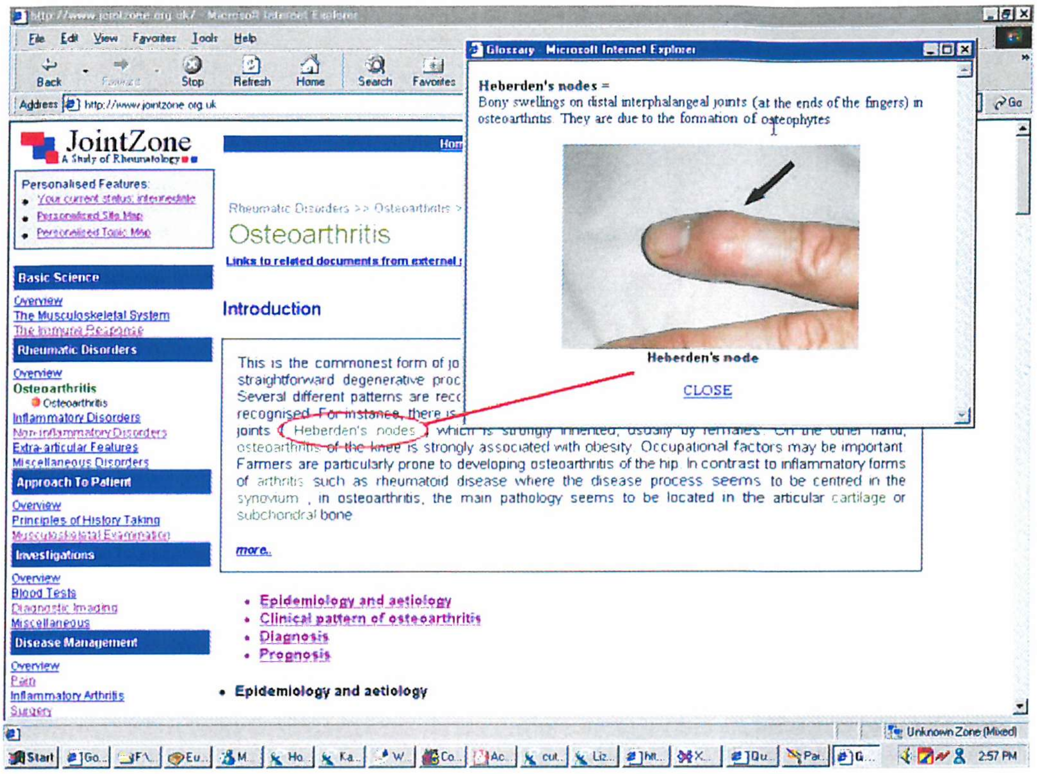


FIGURE 4.12: Glossary links in JointZone that brings up a new window displaying the definition for a glossary word

session. The link destinations (entries of the glossary words, their associated explanations, images or video clips) are stored in a glossary linkbase (see Figure 4.13). The glossary words in the document are highlighted in green and the links are resolved at real time whenever the user clicks on the words. The logical structure of the XML glossary linkbase is represented as a tree structure using the Document Object Model(DOM) [3] (Homer 1999; Hors, Wood, Champion, and Byrne 2000). Whenever a glossary link is resolved, the tree structure provides a quick search through the DOM objects (glossary entries). A matched DOM object will then be retrieved and displayed in a pop-up glossary window using JavaScript[4] (Flanagan 1998).

4.4.2.2 Maintenance of referential links

Adding a new glossary term: It is possible to add a new glossary term to the application at any time. A software tool is used to parse all current documents in the domain to insert markup tags for any occurrence of this glossary term. This process is done offline and automated. The new glossary term is then added as a new entry to the glossary linkbase.

[3]DOM is a platform- and language-neutral interface that allows programs and scripts to dynamically access and update the content and structure of documents.

[4]JavaScript is a scripting language used to control browser behaviour and content.

```
<?xml version='1.0'?>
<!DOCTYPE GLOSSARY [
<!ELEMENT GLOSSARY (GLOSS+)>
<!ELEMENT GLOSS (EXPLANATION,IMAGE*, POPUPVIDEO*)>
<!ELEMENT EXPLANATION (#PCDATA)>
<!ELEMENT IMAGE (#PCDATA)>
<!ELEMENT POPUPVIDEO (#PCDATA)>
<!ATTLIST GLOSS ID CDATA #REQUIRED>
<!ATTLIST IMAGE height CDATA #REQUIRED>
<!ATTLIST IMAGE width CDATA #REQUIRED>
<!ATTLIST POPUPVIDEO FILENAME CDATA #REQUIRED>
]>

<GLOSSARY>
<GLOSS ID="adhesive capsulitis">
<EXPLANATION>a synonym for frozen shoulder.</EXPLANATION>
</GLOSS>
<GLOSS ID="goniometer">
<EXPLANATION>A device used for measuring the
range of joint movement.</EXPLANATION>
<IMAGE width="293" height="228" >glos_gonio.jpg</IMAGE>
</GLOSS>
...
<GLOSSARY>
```

FIGURE 4.13: The glossary linkbase in XML format.

Making changes: Any changes to a glossary term, e.g. a modification to the current explanation, addition of an image or a video clip etc, need only be done once in the glossary linkbase and the update will be propagated to any of the existing glossary links in the domain.

Removing an existing glossary term: Removing an existing glossary term from the domain is possible, although this is not common in this application. The procedure involves an offline process that parses all current documents to remove the markup tags for that particular term. The related entry in the glossary linkbase is then removed.

Adding a new document: Any new document will be processed for the insertion of markup tags for each of its term that appear in the glossary linkbase. The glossary links will appear once the new document is online.

4.4.3 Associative Links

The idea of generating associative links comes from the usual behaviour of a user browsing in the current context wanting to find out more about a particular concept (Lowe and Hall 1996). Unlike structural links that define the logical structure of a hypermedia space, associative links are defined by the semantics of the content. The semantics could be a common concept that groups two or more documents together. For example in the navigational context, when a user is reading a document about concept 'X', the associative links can be followed to find out more about 'X' in other documents. Hence, these links are called associative links because they associate two or more documents together based on a common ground, such as a common concept.

In JointZone, associative links bind internal and external documents together that share the same context. For example, when a user is looking at the context of a disease such as - '*osteoarthritis of the knee*', they could follow associative links to find out more about the general concept of '*osteoarthritis*' or disease management on '*knee surgery*' within the application. Users also have access to documents from external domains by following a link that is available in every document as '*links to related documents from external sites*'. In this case, the associative links interconnect documents in JointZone with documents from external sites (see Figure 4.14).

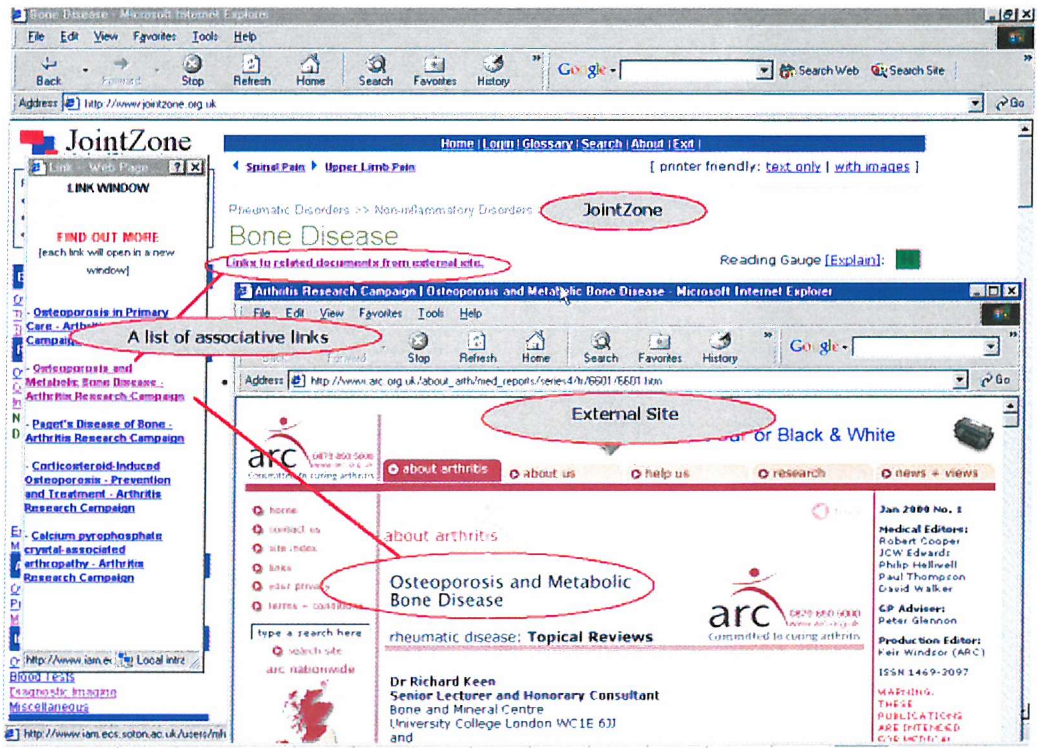


FIGURE 4.14: Associative links interconnecting internal document in JointZone with external pages on the same context.

4.4.3.1 Implementation of Associative Links

Associative links are stored in linkbases where each link is indexed or retrieved based on a keyword or concept. As shown by the illustration in Figure 4.15, the domain expert

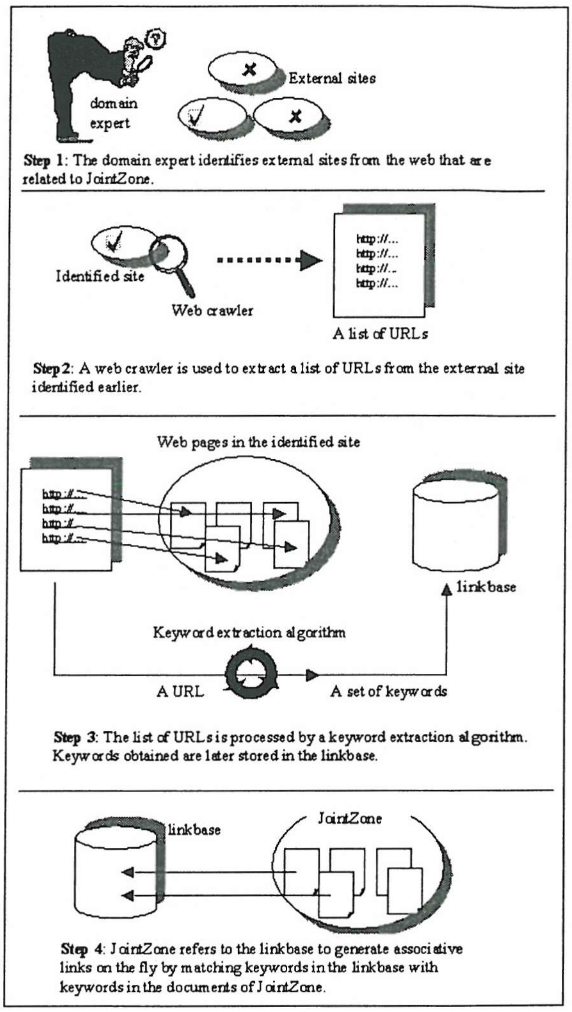


FIGURE 4.15: The implementation of associative links interconnecting foreign sites with JointZone.

first identified external sites that were related to JointZone. Once a related site was found, a web crawler[5] was used to extract a list of URLs from this site. The pages referenced by the URLs were then input into a keyword extraction program to produce indexing terms for each document. Any keyword extraction algorithm can be used but on this case, the 'mutual information' algorithm (Godby 1994) was adopted. The reasons why this algorithm was chosen were, firstly, it produces double-word indexes that give more meaningful representation of the documents as compared to individual words and secondly, the statistics used in calculating the significance of a pair of keywords is based on a full text rather than the whole domain. This is important as it is often difficult to predict the number of documents that are contained within an external site. This algorithm takes advantage of the mutual information statistic that identifies pair words where the probability of its two words x and y, appearing together is higher than the

[5] a software package that parses HTML tags to extract data and files on the web.

probability of them appearing separately in the same text. The statistic gives high mutual information for compound words (e.g. rheumatoid arthritis) and low mutual information for randomly coupled words such as 'but he'. Only pair words of high mutual information are used as indexing terms as they give more meaningful representation than individual words.

The same keyword extraction process was repeated on internal pages within JointZone. All keyword indices from both JointZone and the external sites were then stored in a linkbase, labeled separately as 'internal' and 'external' link type. When an associative link is followed in JointZone, the system first retrieves keywords from the linkbase for the current document that the user is looking at. These keywords are then used to map with the external links in the linkbase that share the same keyword (using simple one to one mapping). In doing this, documents that share the same concept with the current document were identified.

4.4.3.2 Maintenance of associative links

Adding a new document: When a new document is added to the domain, only the linkbase needs to be updated. Any link to this new document will automatically appear in existing documents since this type of link is resolved at real time (links are not embedded in the documents).

Remove an existing document: When an existing document is removed from the domain, the relevant link entry is deleted from the linkbase and any occurrence of this link in the domain will automatically be removed.

4.4.4 Discussion

Even though more links were created with the different linking strategies, the required authoring effort was minimal since most of these links were generated automatically. In the case of associative linking, it has greatly reduced the effort of a domain expert to sieve through every page in a foreign site to find documents that are related to JointZone.

The use of linkbases as reflected in the implementation of referential and associative links ensures that links are separated from the documents. This concept is in tune with the Microcosm link philosophy (Fountain, Hall, Heath, and Davis 1990):

> *...hypermedia links in themselves are a valuable store of knowledge. If this knowledge is bound too tightly to documents, then it cannot be applied to new data. Instead, it should be pushed away from the documents, into a world of generic knowledge.*

This link philosophy treats links as first class objects in their own entities. Links which are stored as separate objects are reusable in many different documents and even across different domains. In JointZone, the glossary links were reused in the case studies and the associative links are potentially reusable in other applications.

4.5 Usability Study

Usability study in hypermedia is concerned with improving the usability of the user interface of an application (Whiteside, Bennett, and Holtzblatt 1989). This involves optimizing the interactions between users and the computer application to ensure the end product is easy to learn, effective and enjoyable to use from the user's perspective (Preece, Rogers, and Sharp 2002). A usability study was carried out on JointZone to assess the user friendliness of the application. At the same time, the study was used to verify the user interface and the basic functionality of JointZone before any adaptive features were integrated. However, a full-scale usability study can be too expensive to carry out in terms of time, money and expertise needed. Therefore, a 'discount' usability study described by Nielsen (1989) acts as a substitution for the full scale usability study to alleviate these problem. According to Nielsen, this approach does not compromise the result. Two methods were adopted in conducting the usability study of JointZone:

Simplified think-aloud studies (Nielsen 1988) This usability study approach is normally conducted using not more than 5 evaluators and the results are analysed from the notes taken by the experimenters.

Heuristic Evaluation (Molich and Nielsen 1990) Based on the principle that 'different people locate different usability problems'. This type of evaluation relies on a small set of usability heuristics as listed in Table 4.2.

Simple and natural dialogue
Speak the user's language
Minimize user memory load
Be consistent
Provide feedback
Provide clearly marked exits
Provide shortcuts
Good error messages
Prevent errors

TABLE 4.2: The usability heuristics abstracted from (Molich and Nielsen 1990)

The following sections will describe how these two methods were applied to the usability study of JointZone.

4.5.1 Simplified think-aloud studies

Throughout the whole development cycle of JointZone, several simplified think-aloud studies were conducted at various stages, looking at different user interfaces for the application. The outcome which was in the form of the experimenters' comments was fedback into the development cycle for the improvement of and changes to the user interface. Hence, the whole process was an iterative one as shown in Figure 4.16. Feedback from the simplified think-aloud studies contributed to the redesign of a user interface, and the process was repeated until the interface was finalised based on the agreements from the developers and the evaluators. For convenience, the studies were usually performed with the project members involved in the developement process or the researchers from the lab where this work was based. Not more than 5 experimenters were involved at a single time and the studies were mostly focussing on the user interface of the case studies and various adaptive features. For example, one of the major redesigns that was carried out was on the layout of the personalized topic map (see Figure 6.6.2). In this case, the users' comments led to a change on the way link titles are displayed: from hidden link titles (titles that are shown only when users move their cursors over the icons, see Figure 4.17) to direct display of the link titles on the map (see Figure 4.18).

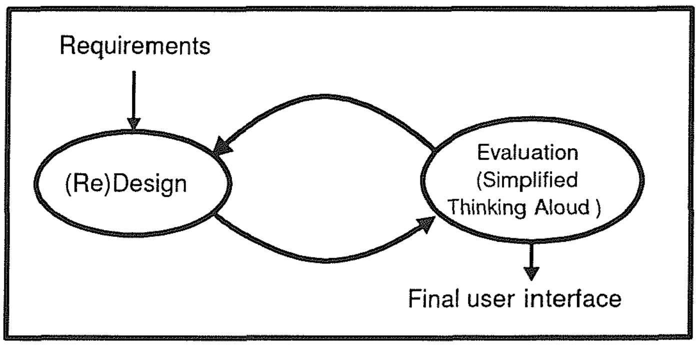


FIGURE 4.16: The iterative developement cycle of JointZone involving 'simplified think-aloud studies'

4.5.2 Heuristic Evaluation

In order to spot any usability problems that were missed in the simplified think-aloud studies, a heuristic evaluation approach was conducted with 29 undergraduate students who were registered for the Human-Computer Interaction (HCI) course module that is part of the BSc in Computer Science at Southampton University. The subjects consisted of 3 females and 26 males with an average age of 19 (stdev = 2.06). The study was designed and carried out online (see appendix B, Figure B.1) where the students were first asked to fill in an online demographic questionnaire (Figure B.2). Then they were shown a list of online instructions (Figure B.3) to guide them to the JointZone web site. Based on these instructions, users had to explore JointZone by observing its structure,

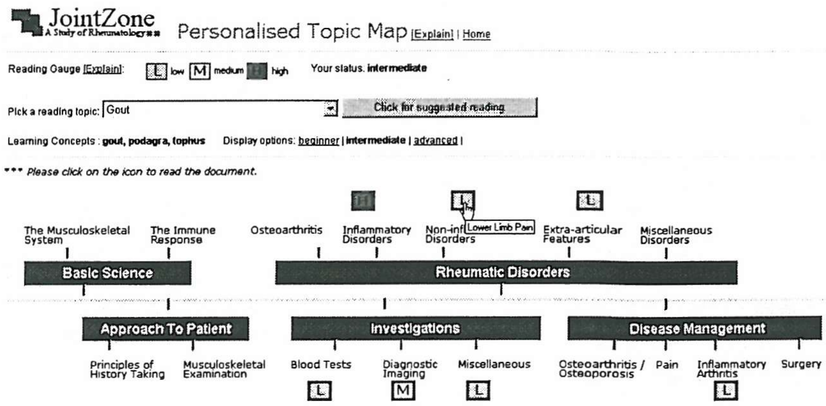


FIGURE 4.17: The original user interface of the personalized topic map where the titles for each link represented by an icon was only shown when the cursor is moved over the icon

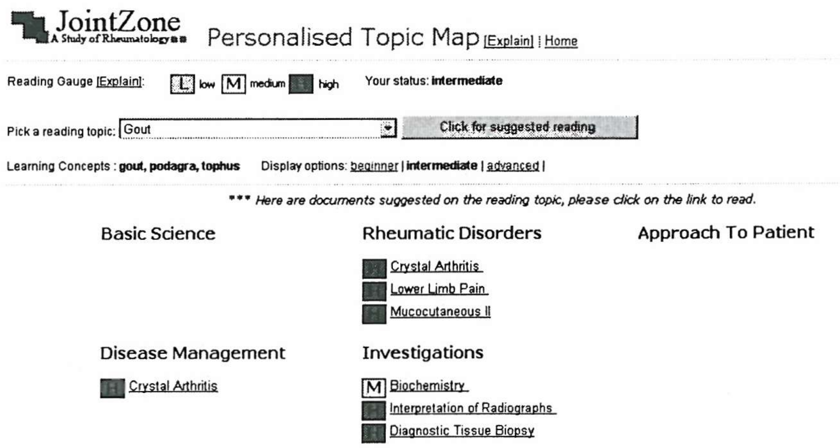


FIGURE 4.18: The changes made to the same map as in previous figure where the title of each link is shown directly beside each icon.

navigation facilities and presentation styles. They were also asked to look up the meaning of a medical term using the site, locate a document and attempt an interactive case study. Finally, they were asked to complete an online feedback questionnaire (Figure B.4). The questions chosen were based on a list of guidelines suggested by Preece (2000) for evaluating websites. The categories are:

- navigation - the ease of getting around the site,
- accessibility - the ease of the log in procedure and the pages loading time,
- presentation - the site layout and graphical design,
- subjective feedback - the users' general opinion of the site from HCI point of view.

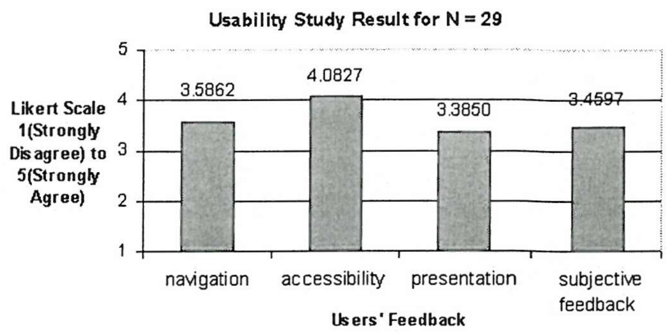


FIGURE 4.19: The usability result of JointZone on the Likert Scales

The usability result was calculated by dividing the total feedback score on the Likert Scales [6] by the number of users and the number of questions for each category (see Appendix B: Table B.1).

As seen from the chart (see Figure 4.19), the result shows no major concern with the overall usability of the website since all four categories achieved an average score of above 3, where 3 is the 'neutral' level on the Likert scale and scores above 3 represent positive user feedback. The accessibility perspective of the website gained the highest score. This is encouraging as most subjects were using a relatively slow connection (accessed from home) during the study.

4.6 Summary

This chapter has provided a description of JointZone, where it has covered the implementation aspect of the basic structure, case studies and link generation. Two methods of usability study: simplified think-aloud studies and heuristic evaluation were adopted to evaluate the usability of JointZone. The results shows a relatively good rating in the usability of the website with the acessibility aspect gaining the highest score on the Likert scale. This usability study is an important measure to ensure the smooth running of the basic system before the integration of any adaptive features. The following two chapters will touch on these adaptive issues.

[6] A measurement widely used for evaluating user satisfaction in terms of opinions, attitudes and beliefs.

Chapter 5

Adaptive Hypermedia

5.1 Introduction

In Chapter 2, an overview of *hypermedia* was presented and a hypermedia application can be summarised as a corpus of information enhanced by navigation and browsing facilities.

Logically, users should benefit from having access to large collection of resources, where information is easily obtainable, often at the click of a button. However, too much information can result in low efficiency of the human mind to absorb and process useful information. 'Information overload' and 'lost in hyperspace' (Conklin 1987; Thuring, Hannemann, and Haake 1995) arise when users begin to encounter too much irrelevant information while searching for useful information or they are confused by maze-like navigation paths while browsing through the information space. Adding to this complication is the fact that each user is different. Users with dissimilar interests and goals will be interested in different kinds of information or different links. Therefore, traditional hypermedia systems that took the design approach of 'one-size-fits-all' find it hard to cater effectively for a group of heterogeneous users (Brusilovsky 1996).

One solution is to control the availability of information to individual users by personalizing the user environment: giving the right piece of information to the right person at the right time. *Adaptive hypermedia*(AH) is a possible solution. AH research seeks to include user modeling in hypertext(hypermedia) in order to improve the hypermedia usability (Brusilovsky 2001a; De Bra, Brusilovsky, and Houben 1999). AH serves to adapt its information based on the user's characteristics (knowledge, background and interest etc) and also to protect users from getting lost or confused in the information space by displaying only relevant information or providing them with the necessary navigational support.

Based on the Dexter model[1] (De Bra, Houben, and Wu 1999; Halasz and Schwartz 1994), an adaptive hypermedia system normally consists of:

- a *user model* that describes the user's characteristics, i.e domain knowledge, preferences, interest, browsing history etc.
- a *domain model* that describes the content at a conceptual level.
- an *adaptation model* that describes how adaptation of content to the users can be done based on the user model.

In short, an adaptive hypermedia system keeps track of the evolving characteristics of the user and stores them in a user model. The system then uses this information to adapt the visible aspects of the system (normally defined in the domain model) to the users. According to Brusilovsky (2001a), an adaptive hypermedia system should satisfy the criteria below:

- it should be a hypertext or hypermedia system,
- it should contain a user model,
- it should be able to adapt the hypermedia to its users using this user model.

This chapter first describes the forms of adaptation that can be applied in hypermedia. Then the role of user modeling and domain modeling is examined by studying the various modeling approaches. Finally the chapter ends with some examples of educational adaptive hypermedia systems by focusing on their design methodologies and evaluations.

5.2 Levels of Adaptation

According to Brusilovsky (2001a), there are two levels of adaptation: content-level(also known as adaptive presentation) and link-level (also known as adaptive navigational support). Adaptive presentation adapts the content of a page to the user by presenting different versions of the same piece of information based on the user model. Adaptive navigational support adapts to users by presenting links in different styles.

[1]a hypertext model containing 3 layers: run-time layer (deals with user interface issues), storage layer (a hierarchical of databases interconnected by links) and within-layer component (contains the content and structure within the nodes)

5.2.1 Adaptive presentation

Brusilovsky (1996) and De Bra (De Bra, Houben, and Wu 1999) suggest three *methods* of applying content-level adaptation:

- *additional explanations or comparative explanations*, display more or less details depending on the user's knowledge of the domain. For example, introductory explanations may be added for novices and advanced details for the expert.
- *explanation variants*, present a different version of the same piece of description based on the user's knowledge. In this case, the system stores more than one variant of explanation for the same concept.
- *content sorting*, display the sequence of items on a page differently to different users.

In order to achieve adaptive presentation above, various techniques have been proposed as mentioned in (Brusilovsky 1996):

- *conditional text*, the system presents certain chunks of information only when the condition is true. This is a low level technique which requires higher authoring effort since all required conditions may need to be set manually.
- *stretchtext*, the system presents a 'stretchable' and 'collapsible' hypertext, meaning when a hot word is clicked, an expanded stretch of text will replace the word. Thus on a page presented to a user, the stretchtext extensions which are non-relevant to the user's knowledge or preference will appear collapsed and the relevant extensions will appear uncollapsed (or stretched).
- *page variants*, the simplest adaptive presentation technique used to implement explanation variants. The system shows different pages to different user to explain the same concept.
- *fragment variants*, more fine-grained implementation of explanation variants where the system displays different variants of explanation for different users.
- *framed-based technique*, the most powerful technique where content is represented in frames, the system decides which frame to display and in what sequence based on a set of rules.

5.2.2 Adaptive navigational support

Adaptive navigational support (ANS) provides link level adaptation to alleviate orientation problems in hypermedia due to rich link structure. In this case, either the number of links suggested to users is variable or the links are annotated to guide users according to their relevant knowledge level or interest. Various ANS techniques have been implemented in the AH community and a comprehensive list of techniques is described in (Brusilovsky 1996) as summarised below:

- *Link hiding* is achieved by hiding and disabling the functionality of irrelevant links in an attempt to limit users to only the set of links relevant to their goals or interests. This method is sometimes controversial, as some users would want to see all the links that other users see. Examples: Hypadapter (Hohl, Bocker, and Gunzenhauser 1996), ISIS-Tutor (Brusilovsky and Pesin 1994)
- *Link sorting* can be done by reordering links from the most relevant to the least relevant. Unlike the previous case, all users are exposed to the same set of links but in a different order according to the sorting. Example: Hyperflex (Kaplan, Fenwick, and Chen 1998)
- *Link annotation* is achieved by annotating links with extra information. For example two different colour balls are used to annotate links to indicate whether the link is ready or not for the users. Example: ELM-ART (Brusilovsky, Schwarz, and Weber 1996)
- *Direct guidance* is the most popular method for link-level adaptation. It is often seen as the 'next' button in a navigation path to guide the user directly to a relevant page. Example: ISIS-Tutor (Brusilovsky and Pesin 1994)
- *Map adaptation (Adaptive hyperspace map)* - The system creates a hyperspace map dynamically based on a user's current goals to provide orientation around the hyperspace. Example: HYPERCASE (Micarelli and Sciarrone 1996)

All the methods described above can be used in combination. For example, link sorting and link annotation can be applied to an adaptive hyperspace map or ultimately both adaptive presentation and adaptive navigational support can be combined to present a hypermedia application that adapts to the users.

5.3 The Role of User Modeling

A user model (UM) is a system representation of the users and is accessed by the functions of *initialization*, *update* and *retrieval* (Kobsa and Pohl 1995). User modeling plays a significant role in an AH system, as data about users needs to be captured before any information can be adapted to the user's requirements. It is a prerequisite for a personalized interaction between the system (computer) and its users. The system models the users by keeping a record of *representation* of their *cognitive* and *behavioral* attributes. For example, the cognitive attributes include the users' knowledge level in the domain, their interest and preference in a particular piece of information, their attitudes or browsing styles in the hypermedia environment. On the other hand, the behavioral attributes are concerned with the users' activities in the hyperspace, for example, a particular browsing trail that they have followed, or a history of pages that they have visited.

Based on literature, user modeling can be categorized according to:

- the approach taken, e.g. how and what aspect of the user is being modeled.
- the way it is constructed, e.g. how much input from the user is involved (implicit or explicit).

The issues above are further described in the following sections.

5.3.1 User modeling approaches

Various approaches have been taken in both the AH and the user modeling communities in an attempt to capture representations of users. Some classical approaches are outlined in the following, Table 5.1 compares the benefits and shortcomings of these approaches.

5.3.1.1 Stereotype model

A person is often stereotyped by his/her characteristics. For example our impression of a computer hacker is normally a person wearing thick glasses, with long hair and haggard looking jeans. Although these attributes are not necessarily true for a computer hacker, we tend to make this assumption until it is proven otherwise.

Rich (1979) defined the stereotype user model as one where the system infers information about users based on a collection of frequently occurring characteristics of users. The motivation comes from two reasons. Firstly, if we want to infer knowledge about each individual user, one possibility is to interview them, but this is obviously time consuming and it will take a large number of questions to accumulate the knowledge the system needs. This seems to be an impractical way. Secondly, the users may not always give correct answers. Evidence in psychology literature has shown that people are not a reliable source of information about themselves (Nisbett and Wilson 1977) . Hence, stereotype-based reasoning is potentially a better alternative for accumulating information about users with the least amount of required effort. Based on stereotyped impressions of a user, a more detailed model, starting from small amount of facts, can be built. Stereotype-based reasoning is by far the most popular method used to build initial default models of the user.

A good example is Grundy (Rich 1979) where the system plays a librarian. The system identifies books to recommend to its users based on stereotyping. For example, a user might say she is a feminist. Grundy uses this as a trigger for a large number of stereotypic inferences about the user (facets). In this case, Grundy may infer that she most likely is active in politics, has personal attributes such as independence and high perseverance, and has an important role in the issues of sexual-openness and upbringing. Grundy makes recommendation on books that match these facets. The user then gives feedback on these recommendations and Grundy refines the user model by adjusting the rating on each facet of the model.

5.3.1.2 Individual model

Whilst the stereotype model is a collection of identical individual user models, the core of the individual model is a model of a unique individual user. This individual user model has to be built on the fly by the system and it must be specified in some explicit ways on how the model influences the overall system (Rich 1983). The individual model is normally built from a combination of information directly provided by the user, inferences from the user's actions and predictions made from the stereotype model (Rich 1979).

5.3.1.3 Overlay model

The overlay model (Carr and Goldstein 1977) is used commonly in intelligent tutoring systems. It is called 'overlay' to reflect the representation of the student knowledge as a subset of the expert knowledge. In this representation, the model serves as a goal for the students to achieve; just as in real life, the goal of the students is to achieve the knowledge base of an expert. In the overlay modeling, the system keeps track of the confidence level that a user has to achieve for a given skill or a particular topic in the domain. The threshold set for successful achievement of a particular skill or performance target is based on the perspective of the expert. For this reason, the system assumes only the knowledge base of an expert and does not address the situation where the student might possess incorrect assumptions or alternative knowledge which do not exist in the expert knowledge base.

5.3.1.4 Modeling by machine learning

The field of machine learning is concerned with constructing computer programs that automatically improve with usage. In this case, user modeling by machine learning facilitates an automatic process of learning from data to recognize and characterize behaviour of users (Webb, Pazzani, and Billsus 2001; Sison and Shimura 1998; Pohl

1996). This type of automated reasoning caters for the uncertainty in a user model and provides more dynamic information acquisition of users. Another advantage of using the machine learning approach is that it provides an unobtrusive way of learning about users (Goecks and Shavlik 2000), eliminating the problem of possible users' frustration due to system intrusions.

UM Approaches	Advantage	Shortcoming
Stereotype Model	less effort to build	collection of identical user representation, no unique case for each user
Individual Model	unique individual representation	model must specify explicitly how it influences system
Overlay Model	set goals for users based on expert knowledge base	does not address alternative knowledge
Machine Learning	automated unobtrusive reasoning, caters for uncertainty in UM	requires training data, takes time to build up

TABLE 5.1: The comparison between various user modeling approaches.

5.3.2 User modeling methods

Based on the research literatures in both AH and user modeling, user models can be grouped according to the method by which they are constructed:

5.3.2.1 Implicit

Implicit user modelling is carried out transparently to the users without interrupting their normal interaction with the system. The system can learn about the user's interests and goals by unobtrusively observing their normal behaviour. For example, in (Goecks and Shavlik 2000) the system analyses the number of hyperlinks the user follows, the amount of scrolling activity and the amount of mouse activity on a page to predict a user's interest in that page. On a more sophisticated level, machine learning is used to build user models in an intelligent way. In MANIC (Stern and Woolf 2000) the system predicts users' preferences with regard to the presentation style of content (graphic or text) based on machine learning using the Naive Bayes Classifier technique. This mechanism of drawing inferences implicitly has contributed to the automation of user modelling, but unfortunately, the complexity and sophistication of such systems can sometimes handicap their practicality (Kaplan, Fenwick, and Chen 1998). In most machine learning applications, a number of training examples are needed to generate an accurate user model and these examples often rely on users' explicit feedback.

5.3.2.2 Explicit

Explicit user modelling allows the user to state explicitly their preferences or background knowledge. In this case users are often asked to complete a questionnaire or a list of options before they start using the system. Users will be asked to rate a visited link or page in order for the system to infer their interests or goals. This approach is popular for AH systems, (e.g. Hypadapter (Hohl, Bocker, and Gunzenhauser 1996)) because it is a cheap and direct way to produce a reasonably accurate user model. However, the approach falls short for users when it is seen as an interruption to their normal interaction with the system. On a practical level, users usually do not prefer to be delayed by a long list of questions before they can get on with what they intended to do with the system.

Property	Implicit	Explicit
Acquisition Mechanism	Auto-learn from data and users' behaviour to make recommendation	Users state preference explicitly
Advantage	Unobtrusive monitoring	Simple and reasonably accurate
Shortcoming	Error prone and sophisticated	Static and interrupt normal interaction
Evolvement	Recommendation change overtime with users' new behaviour	Status change manually by users

TABLE 5.2: The comparison between implicit and explicit user modeling.

5.3.2.3 Discussion

Table 5.2 compares the benefits and shortcomings of both explicit and implicit methods in user modeling. Jack Aaronson (2002) has suggested that an ideal approach is to combine both methods in order to capture the synergy between them. The idea is to initialize a user model using an explicit approach, such as a questionnaire, for its simplicity and accuracy. Once the user model is established, the implicit method can then take over to infer more information based on users' behaviour. In this case, the model acquisition process will be done unobstrusively to the users. And the user model can evolve automatically to adapt to the dynamic characteristics of the users.

5.4 The Role of Domain Modeling

The domain model describes the content of a domain. In other words, the domain model is basically a representation of the domain knowledge and it describes how the content is 'labelled' or 'organised' before any adaptivity is made feasible. To date, there is no standard definition to describe the components that exist within a domain model. Nevertheless, a general example is scrutinized as below:

De Bra et. al. (De Bra, Brusilovsky, and Houben 1999) defined domain knowledge as *concepts* in a domain which exist in three forms:

- *atomic concepts / fragments*: the smallest unit of information
- *pages*: a cluster of fragments
- *abstract concepts*: larger units of information

These three forms of concept are different in terms of their granularity in domain representation. At the coarse-grained level, the domain can be organised based on the page structure that exists. On the other hand, atomic concepts can be used to represent knowledge in the domain at fine-grained level. Hence, the decision is essentially application dependant.

After the granularity of the concepts is determined, the relationship between the concepts needs to be expressed. The pre-existing type of relationship is the *links* that interconnect pages in the hypermedia. These are called *generic relationships*. There are also *prerequisite-based relationships* which are commonly adopted in most educational AH applications. Through this type of relationship, the domain is organised into prerequisites, remedial and outcome categories. Finally, there are the *history-based relationships* which group pages into visited and not visited categories in a domain.

5.5 Previous Work in Adaptive Hypermedia

Education was one of the earliest application areas for adaptive hypermedia (Brusilovsky 2001c). It is also one of the most promising application areas for adaptive hypermedia (Brusilovsky and Eklund 1998). It is seen as such because there are many aspects of students that can be modeled (i.e. knowledge, interest and browsing history), which in turn provide more possibilities for adaptation.

Generally, adaptive hypermedia is applicable to any hypermedia system with a reasonable sized corpus of information, and preferably, one which is expected to be used by different groups of users.

Besides education, some of the recent and more popular areas for AH applications are:

- *Information retrieval*, e.g. digital journals (Bollen 2000)
- *Commercial*, e.g. TV guide (Cotter and Smyth 2000), online newspaper (Billsus, Pazzani, and Chen 2000)
- *Online kiosk*, e.g. tourist guide (Cheverst, Davies, Mitchell, and Smith 2000)

For the purpose of this thesis, we will focus on AH systems developed in educational settings. Some of the classical AH educational applications are discussed in the following sections in terms of the user modeling, the domain modeling and the adaptation approach taken. Evaluations that have been carried out for some of the systems will also be discussed.

5.5.1 ELM-ART

ELM-ART (Brusilovsky, Schwarz, and Weber 1996) which stands for *Episodic Learning Model with Adaptive Remote Tutor*, is a classical example of an AH system designed for a LISP programming course. The system is capable of diagnosing incomplete and complete solutions to problems and providing individualised help to students.

User model: The UM is based on individual user models comprising a collection of episodes (Brusilovsky and Weber 1996). These episodes contain information about the concepts and rules needed by the users to produce program codes to solve programming tasks. The individual episodic learner model is thus closely related to the domain knowledge since each episode is stored with respect to the subject domain.

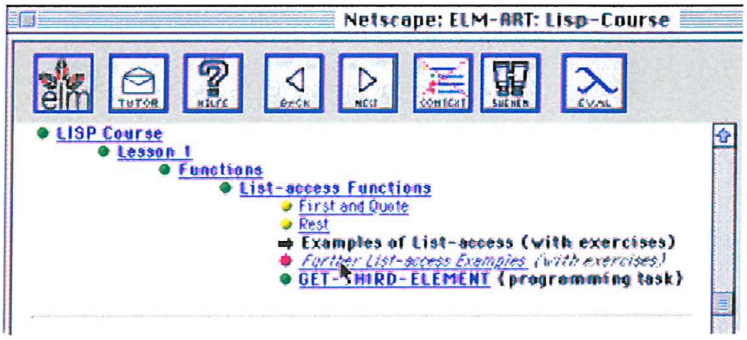


FIGURE 5.1: A screenshot of the ELM-ART system abstracted from (Weber and Specht 1997)

Subject domain representation: The subject domain was divided into small subsections associated with concepts to be learned. The domain expert provides a clear insight into the prerequisite and outcome concepts involved in the course. These prerequisites and outcomes formed a conceptual network that relates concepts to one another, providing a basis for adaptation in the following section.

Adaptation: Adaptation is performed based on the conceptual network. Users are guided explicitly to concepts where their prerequisites are fulfilled. Adaptive link annotation is used in ELM-ART (see Figure 5.1) where colour balls of 'red', 'green' and 'yellow' denote concepts of 'not ready to be learned', 'ready and recommended by the system' and 'ready but not recommended by the system' respectively. For example, a concept is 'ready to be learned' if its prerequisite concepts are fulfilled. This link annotation is developed further in InterBook (see 5.5.2) as an online textbook. However in both Interbook and ELM-ART, the system cannot determine whether the user has really learned by visiting a page. This limitation motivated the development of ELM-ART II (Weber and Specht 1997) which provides adaptive guidance on top of the existing link annotation.

In ELM-ART II, the system keeps a static slot that stores prerequisites and outcomes for concepts. A dynamic slot is also created for each individual user providing test items (i.e. quizzes) to infer concepts that are understood by user. Information from the dynamic slot annotates links and guides the user through the course.

Evaluation: An experimental study was carried out on ELM-ART II to look at the effect of combining the adaptive link annotation technique with the adaptive guidance offered by the NEXT button (Weber and Specht 1997). Two treatments were investigated with subjects being randomly assigned to one of the four treatment conditions as shown in Table 5.3.

Treatment	Experimental group	Control group
1	adaptive link annotation	simple annotation of links as visited and not visited
2	with NEXT best steps button	without the NEXT button

TABLE 5.3: Allocation of subjects in the experiment for ELM-ART II

The first hypothesis for this experiment was that both the adaptive annotation of links and individual sequencing with the NEXT button will motivate users to proceed with learning (e.g. work on more pages). The study showed a significant effect of the NEXT button on subjects who were beginners in programming language. In this case, subjects who have the usage of the button worked on about 10 pages more than subjects without such a button. However, the adaptive link annotation was found to have no significant effect on the beginners in programming language. Nevertheless, subjects who were familiar with at least one programming language visited more pages and solved more exercises when working with adaptive link annotation.

The second hypothesis was that the number of navigation steps is to be reduced by both the adaptive link annotation and individual curriculum sequencing with the NEXT button. However the result revealed that there is no statistical differences in the number of navigation steps with or without adaptive link annotation, and similarly with or without the NEXT button. Further analysis showed that most users only followed the system's guidance in the initial stage of the experiment and as they got used to the simple hierarchy structure of the programming course, they continued using the system without relying on the system's guidance.

This experiment has concluded that the adaptive guidance offered by the NEXT button were especially useful in the starting phase of the interaction with ELM-ART II, particularly with beginners. On the other hand, the adaptive link annotation created more learning effect (based on more pages visited and more exercises solved) on users who were familiar with the domain than on beginners. Hence this shows that AH is not necessarily always helpful to all users, but this study has identified the potential types of users that will find certain adaptive techniques helpful.

5.5.2 InterBook

InterBook is a tool for developing adaptive Web-based courseware (Brusilovsky, Eklund, and Schwarz 1998). Its approach is to develop an electronic textbook that consists of hierarchically structured hypermedia materials.

Domain Model: The domain model consists of a set of domain concepts such as topics, knowledge elements, objects and learning outcomes. The granularity of the concept elements is dependent on the area of application. The domain concepts are represented as nodes and connected through links. This forms a conceptual network where the links between the nodes represent the relationships between concepts - prerequisite or outcome. A concept is considered as prerequisitional if the student needs to know this concept in order to understand the content of a unit of domain. A concept is considered as the outcome concept if the current studied unit in the domain presents the piece of knowledge designated by this concept.

User Model: The user model stores an estimation of a student's knowledge for each domain concept (overlay model). These values in the UM is increased or decreased according to the user's action such as page visit, problem-solving and quizzes answering. The UM also stores a set of student's learning goals. A learning goal is a set of concepts to be learned. A sequence of learning goals that is specifically assigned to a student will contribute to that individual's learning sequence. Adaptive guidance is thus made possible through this mechanism.

Adaptation: The InterBook system provides all the regular navigation tools that allow sequential and hierarchical links. These links are generated on-the-fly based on the student's current knowledge level represented in the UM. InterBook uses adaptive annotation of a traffic light metaphor to represent the type and educational state of each link: green bullet for 'ready to be learned' node, red bullet for 'not ready to be learned' node and white bullet for 'clear and nothing new' node. A checked marked is added for visited page (see Figure 5.2). InterBook also provides direct guidance to the students by suggesting the next part of the material to be learned. For example, when students have difficulties understanding some explanation or solving problems, the reason could be the that some prerequisite materials are not understood well. In this case the system can provide pre-requisite help as a direct guidance to point students to the background concepts.

Evaluation: 25 undergraduate students who were enrolled in the teacher education course took part in an evaluation, over a period of four weeks, to study the effect of UM based link annotation on student learning and their navigational paths (Brusilovsky and Eklund 1998). The hypothesis of this study was that the adaptive link annotation would support students to achieve more efficient paths through the knowledge space, with improved learning outcomes. During the evaluation session, knowledge tests and questionnaire were given to measure knowledge acquisition and to collect feedback. Audit trails were also carried out to capture the users' learning paths. In the first session, the system was used by all subjects, who answered questions on its features. In the second session, the students were randomly divided into 2 groups and were exposed to different versions of the system as shown in Table 5.4.

Group 1	Group 2
Database chapter WITH adaptive link annotation n= 12	Database chapter WITHOUT adaptive adaptive link annotation n =13
Spreadsheet chapter WITHOUT adaptive link annotation n = 12	Spreadsheet chapter WITH adaptive link annotation n = 13

TABLE 5.4: Allocation of subjects in the experiment

In the third session, both groups of students swapped systems, with those who had been exposed to the adaptive system being given the system without adaptation and vice-versa.

The initial result of the study showed a statistically significant negative effect on the use of adaptive link annotation, in terms of the test result. Further analysis revealed that this was caused by the differences in students' browsing behaviours. Most of the students relied more on the non-adaptive features such as 'back' and 'continue' buttons than on using the annotated links available. Also, some of the students already have prior experience with the domain, hence the ANS have very little effect on their learning process. Nevertheless, further analysis showed that for those who showed a high level of acceptance towards the AH features, i.e. those who followed closely the advice from the system, they performed better in the given test. The study has also concluded that user model based link annotation seems to be of value only to those who agree with it (those that accept and follow the annotation).

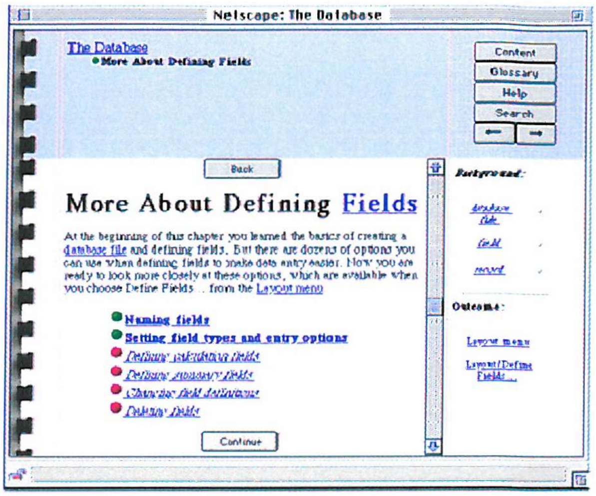


FIGURE 5.2: The textbook view of InterBook with adaptive link annotation. Green bullet means recommended, red bullet means 'not ready to be learned', white bullet means 'nothing new', while a checked bullet means 'visited', abstracted from (Brusilovsky and Eklund 1998).

5.5.3 AHA!

AHA! (which stands for *Adaptive Hypertext Architecture*) is an AH application for navigating through instructional courses on the web (De Bra and Calvi 1998). AHA! deviates from the AHAM reference model [2] (De Bra, Brusilovsky, and Houben 1999) where the domain model and adaptation model are tightly coupled. This means that both the information about the domain and the adaptation performed are stored together.

Domain / Adaptation Model: In AHA!, concepts and pages are represented together with their associated adaptation rules using XML files or database tables. Pages in AHA! are linked through 'generate' and 'requirement' relationship (De Bra and Ruiter 2001; De Bra, Aerts, Smits, and Stash 2002). These relationships play an important role in updating the user model and performing the adaptation.

Table 5.5 shows an example of an XML-based description of a page named 'dekonick' in the domain. The *requirement* attribute decides the condition of this page if it is to be shown as desirable (good link), the *generate* attribute defines the actions to be taken to update the user model. For example, this page will be shown as a good link if the user's interest in beer is greater than 20. Each access of this page will trigger an update to the user model whereby the attribute of beer interest is increased by 10 and chocolate interest is decreased by 5. There is an authoring interface available for author to define the generated relationships when building an application.

[2] AHAM is an adaptive hypermedia framework based on the formal Dexter model for hypermedia.

```
<concept>
  <name>de-koninck</name>
  <desc>Beer from Antwerp</desc>
  <attribute name = "access" type = "bool" isPersistent= "false">
      <desc>standard attr:true when page accessed</desc>
      <generate>
          <requirement>beer.interest < 100</requirement>
          <trueAction>beer.interest += 10</trueAction>
      </generate>
      <generate>
          <requirement>chocolate.interest >= 5 and
          chocolate.interest < 50</requirement>
          <trueAction>chocolate.interest -= 5</trueAction>
      </generate>
  </attribute>
  <attribute name = "interest" type = "int" isPersistent= "true">
  ...
<\concept>
```

TABLE 5.5: A syntax showing how domain and adaptation rules are defined in AHA!, as abstracted from (De Bra, Aerts, Smits and Stash 2002)

User Model: AHA! maintains a user model based on how the user relates to the web pages or concepts, i.e. their interest or knowledge. Each time a user visits a page, a set of *generate* rules determines how the user model is to be updated. This is an adoption of the overlay model where every concept and attribute in the domain model is represented as a concept or attribute in the user model. These values of the attributes can exists as Boolean, percentage or named values such as 'no knowledge', 'know about', 'read about' and so forth.

Adaptative features: AHA! provides both adaptive content and adaptive linking. Adaptive content is provided through content fragment variants where the start-page of the course changes automatically after the user logs in for the second time. This is made possible through conditional content. The relevant content is only displayed if the user model matches with the condition in the statement. The adaptive linking techniques used include link hiding (irrelevant links are hidden from the users), link removal, link disabling (a link is still visible but its functionality is disabled) and link annotation. Direct guidance is also provided by the system offering the best next page to follow depending on the user's knowledge state.

Discussion: AHA! is a flexible generic adaptive hypermedia system that promotes simplicity in its approach to build different types of adaptive applications. It has adopted a rule-based overlay method that specifies how the domain is to be adapted to the user. It is clear that this nature of adaptive application development requires a significantly huge effort from the author/domain expert to define the sets of adaptation rules. There is a closely coupled relationship between the author of the domain and the author of the adaptive application. Generally, the author of the adaptive application needs to know the domain well in order to define the adaptation rules, e.g. how concepts relate to one another in the domain.

In terms of gauging a user knowledge or interest, AHA! used a mechanism that is based on the page requested by the users. This can be an unreliable input. To overcome the shortcomings, the user of the AHA! application are given the option to manually alter the user model by means of manipulating the user profile settings on an online form (De Bra and Ruiter 2001).

There is no evaluation to date that has been carried out on any adaptive AHA! application to provide assessment of its effectiveness to users.

5.5.4 ISIS-Tutor

ISIS-Tutor (Brusilovsky and Pesin 1994) is an intelligent learning environment to support the print formatting language of the information retrieval system CDS/ISIS/M for IBM PCs. It is a special example of AH because it abstracts both the advantages of an Intelligent Tutoring System (ITS) and hypermedia. Traditionally, ITSs have been used in educational computer systems to provide intelligent direct guidance. Whilst the rise of hypermedia in recent years promotes an environment for exploratory discovery learning (Boyle 1997), ISIS has proved that both the above are not contradictory ways of using computers in education, but instead can be used together to provide a tool for student-driven acquisition of domain knowledge.

User model: ISIS-Tutor maintains an overlay model representing the user's knowledge for every individual topic in the domain. In general, it keeps a counter for each concept to be learned by user. One of four knowledge states is stored for each topic, namely 'not-ready-to-be-learned', 'ready-to-be-learned', 'in work' and 'learned'.

Domain Representation: The domain model consists of a directed graph of prerequisite relationships between concepts as commonly found in other AH systems like InterBook, ELM-ART and AHA!.

Adaptation: The tutoring component in ISIS-Tutor selects the optimal teaching operation based on the users' knowledge. For example it presents a new concept if the student has already mastered the current concept, otherwise it presents a problem based on the current concept to test the student. Hence this is a provision of an adaptive sequence of tasks and concepts aimed towards an individual student's knowledge. The hypermedia component in the system provides ANS by annotating the set of links leading from the current node to related nodes according to the current user knowledge and educational goals. It also provides adaptive link hiding to hide all the concepts that are outside the current educational goal for the users.

Evaluation: An experiment was carried out to check the efficiency of combining link hiding and link annotation within an educational context (Brusilovsky and Pesin 1994). 26 subjects (first year computer science students) took part in this experiment where they were randomly divided into 3 groups: group 1 worked with hypermedia without adaptation, group 2 worked with non-restrictive AH (only link annotation) and group 3 worked with restrictive AH, which supports both link hiding and link annotation. The reason for the restrictive version through link hiding is to exclude all 'not useful' information, i.e. not-ready-to-be-learned concepts, from the menus and index in order to reduce cognitive overload of the student. Prior to the experiment, ISIS-Tutor was briefly introduced to the students and they were given ten concepts and ten test problems to work on during the experiment.

The result shows the number of navigation steps, the number of repetitions of previously studied concepts and the number of transitions from one concept to concept and from index to concept are less for the AH application (Group 2 and 3). Moreover, this difference is even less for the non-restrictive AH application. The experiment showed that adaptive visual annotation can reduce user's floundering in the information space and make learning more goal oriented. However, it does not improve the quality of learning, only reduce the number of visited nodes and further reducing the learning time.

5.5.5 MANIC

MANIC (Stern and Woolf 2000) is an online lecturing system that provides adaptive content based on users' knowledge and learning style preferences. It uses a simple grading scheme to determine the appropriate level of adaptation. The system also incorporates machine learning to predict the student preferred style of learning.

Domain Representation: The domain of a lecture course is organised into a semantic network of topics, linked by the relations of prerequisite, outcome and remedial.

User model: The content is given a few levels of difficulty, from the easiest, to easy, medium and hard. Hence, there is a need to capture a student's level of understanding in order to adapt the content accordingly. A pre-test is carried out to determine the students' mastery values before they start using the system. Content which is of one difficulty level higher than the student's highest mastery value will be presented. The system is capable of recognising students' individual learning preferences, for example some students may prefer graphics presentation to textual explanation. The tutor predicts a student's preference through machine learning. The 'Naive Bayes Classifier' technique is used to predict the student preferred learning style by considering his or her previous choice of learning styles.

Adaptation: MANIC uses the adaptation technique called 'stretchtext' to provide supplemental information in the content. The same basic information is presented to all students, but additional supplemental information is attached based on the user model. Besides adapting content according to users' mastery level, the content is also further filtered to determine the user-preferred style of presentation. Hence the final content is customised to both the individual student's knowledge level and to his/her preferred learning style.

Discussion: There is no evaluation being formally conducted on this system. But the author has expressed concern over the mechanism of measuring understanding based on time, where a fixed optimal reading time is set for each page depending on the page length regardless of fast or slow readers. For future work it was suggested that improvement in this aspect can be made by taking into consideration the differences between individuals, i.e. some students may read slower than others, but still comprehend as much. The author suggested the inclusion of a tutor in the system to 'learn' appropriate optimal time values for each individual student as they interact with each kind of object.

5.5.6 HYLITE+

HYLITE+ is a dynamic hypertext system that creates links and page content on demand based on the user's domain background and their previous interaction in the system (Bontcheva 2001a; Bontcheva 2001b). It automatically generates encyclopaedia-style explanation of terms in two specialised domains: chemistry and computers.

In HYLITE+, users interact with the system in a Web browser by specifying a term to look up. The system will then generate a hypertext explanation of the term based on the user model. This work depends heavily on Natural Language Generation (NLG) techniques to create links and pages dynamically. When the user requests information about a topic, HYLITE+ first determines whether it is a domain concept or an instance of such a concept. Then it determines if the concepts are already known to the users. For unknown concepts, this will trigger the inclusion of additional information in the explanation.

User Model: The user model in HYLITE+ captured the prior knowledge of the users. It is initialised when the user registers with the system for the first time. A set of stereotypes (e.g. novice, intermediate and advanced) is assigned based on the information provided by the user. A novice is assumed by default when no such information is provided. The UM is updated dynamically as the user interacts with the system.

Evaluation: Eight users were involved in an experiment where the same users interacted with two versions of the system (Bontcheva 2002). Prior to the experiment, the users' background information such as their prior knowledge, computing experience and familiarity with Web browsers were captured. All users were divided evenly into two groups based on their prior knowledge. The evaluation of this work has shown that the users prefer the adaptive style of explanation (Bontcheva 2001a). One of the highlights of this system is that the user has control over the generator's decision, including disabling all tailoring functions. The evaluation has shown that user's acceptance of the adaptive hypertext systems could be improved if they are allowed to control the system behaviour, e.g. disabling unwanted features. The evaluation also discovered the differences in the users' reading styles, in terms of whether they are skimmers or readers. This pointed out the need to control for this variable in the experiment due to the fact that the reading style influences some of the quantitative measures such as task performance, meantime per task, number of visited pages, and use of browser navigation buttons (Bontcheva 2002).

5.5.7 Dublin's Personalised Learning Service

Trinity College at Dublin developed the Personalised Learning Service (PLS) that adopted a multi-model, metadata driven approach to provide adaptive hypermedia services for personalised eLearning (Conlan, Wade, Bruen, and Gargan 2002). It was used to deliver personalised courses in SQL (Structured Query Language) to final year undergraduate students.

The PLS adopted a multi-model approach where it has three separate models as its design basis: learner (user model), narrative (teaching/adaptation model) and content (domain model) (Conlan, Wade, Bruen, and Gargan 2002). The PLS uses metadata to represent both the content and narrative model. The learner model is stored as an information repository. The uniqueness of this architecture is the separation of the learning content from the adaptive linking logic or narrative. The purpose for this separation is to allow for the possibilities of reusing a piece of learning content as it is no longer specific to a given narrative model.

The narrative model describes the rules that govern the scope and range of the personalized courses. The initial development stage of a personalised course requires the domain expert to describe the learning content requirements of a course, and the instructional designer to describe the pedagogy requirement. It is also the task of the domain expert to prepare the 'candidate content groups' - a few versions of the same content, to fulfil a common content requirement. Similarly, the PLS also has 'candidate narrative groups' that offers different pedagogical approach in structuring learning content in a single course. During a user-interaction session the PLS is capable of selecting a narrative based on the learner model values (e.g. learning style).

User Model: The user model in the PLS represents the users' prior knowledge and learning styles. The initial model is built by asking the student to complete an instrument, typically an online questionnaire that determines both their prior knowledge of the domain and information of any pertinent learning style. The student has access to the questionnaire at any stage during their interaction with the system to modify their learner model. The design of any instruments that determine the learner information is the responsibility of the domain expert and instructional designer.

Evaluation: 80 students who used the PLS for a personalised SQL course completed an evaluation questionnaire (Conlan, Wade, Bruen, and Gargan 2002). The initial findings showed that over 60% of the students believed that the online instruments gave them sufficient control over the content generated by the personalized course and 87% of the students were satisfied with how the content was structured in the PLS. This study has shown that, generally, the student's were satisfied with the personalised courses generated by the PLS even though some of them have expressed the desire for a finer level of content control than what has already been offered via the online instrument.

Discussion: This work has demonstrated that great amount of effort is required from the domain expert in order to develope a personalised learning course. The domain expert is not only responsible for generating the content, but also for defining the narrative rules (for adaptation performance). Though this is an interesting multi-model approach in delivering a personalised service that utilises metadata-based representation of content and separation of content from the narrative model to encourage content reuse, the complication in development might just be a bit to overwhelming for the domain expert.

5.6 Discussion

The literature has shown that in most educational adaptive hypermedia systems (e.g. ELM-ART, MANIC, INTERBOOK, AHA!), the idea of curriculum sequencing is used to construct the prerequisite-based relationship between knowledge units in domain modeling. Materials are grouped manually by the domain expert into prerequisites, remedial and outcome topics. These aggregated learning materials are then presented adaptively to the students based on their current knowledge level. From the perspective of authoring, this method increases the burden on the domain expert to manually design a prerequisite network of the content. In some cases this problem is solved because the application designers are themselves the experts in the information domain, a reason why many educational AH applications are built in the domain of computer science (i.e. AHA!, ELM-ART, ISIS-Tutor, Dublin's PLS and MANIC).

Most of the AH systems maintain a user model that closely resembles the domain - overlay model (see Section 5.3.1.3). The UM stores values which represent a user's knowledge level for each domain concept (i.e. ELM-ART, InterBook, ISIS-Tutor and MANIC). On top of this, MANIC attempted to model the user's learning preference, i.e. preference for graphics or textual explanation. HYLITE+ on the other hand, maintains a more general UM by grouping users into a stereotype - novice, intermediate and advance. The scenerio has shown that most adaptive implementation tends to base strongly on the knowledge of the users and revolve around task-based nature such as locating a piece of information and understanding a concept in the knowledge space. There is not much attention in modeling the user's behaviour particularly in the context of browsing in the hypermedia structure. As pointed out by the empirical study of HYLITE+, there is a possibility to adapt to the reading behaviour of the users, e.g. readers or skimmers. This leads to the potential of integrating adaptivity into free-browsing as well as of task-based activities.

The literature also showed the importance of user control over the functionality offered by the adaptive systems. In HYLITE+ users are given the control to choose, i.e. enable or disable adaptive functionality in the interaction with the system. Empirical study has shown that this will boost user acceptance of the adaptive features in the systems (Bontcheva 2001a).

5.7 Summary

This chapter gives a description of adaptive hypermedia supported by literature background on AH systems. The motivation behind adaptive hypermedia comes from the attempt to alleviate the problems of cognitive overload and disorientation in the information space. Two levels of adaptation are provided by AH, namely content-level and link-level, which are also known as adaptive presentation and adaptive navigational support, respectively. User modeling plays an important role in AH to capture information about the users, either *implicitly* or *explicitly*. The various approaches to user modeling include the *stereotype* model, *overlay* model, *individual* model and *machine learning* model. Domain modeling is concerned with defining the representation of the domain knowledge and expressing a relationship between those knowledge units (prerequisites-based, history-based or generic relationship). Previous research work in adaptive hypermedia, particularly those applied in education, was discussed through seven examples of educational AH applications. The next chapter, Chapter 6 will describe how adaptivity was integrated into a 'baseline' application - a fully functional web-based application. The focus of our approach is to alleviate the involvement of the domain expert, and the adaptive implementation will concentrate on supporting the free-browsing nature in this Web-base application. Chapter 7 will describe an evaluation that has been carried out to assess the effectiveness of integrating adaptivity into an otherwise fully functional web-base application.

Chapter 6

Integration of Adaptivity into JointZone

In the previous chapter, a general background of AH was presented, looking at various components of an AH system with a particular focus of AH systems designed to support educational applications. This chapter focuses specifically on the integration of *adaptivity* into a web-based application, JointZone.

6.1 Motivation

The motivation for integrating adaptivity into JointZone came from the need to provide guidance and navigation support to different types of users. The concept of AH was chosen for this purpose in order to preserve the user-driven exploratory nature of environment. This means the users are still in control and can choose whether or not to make use of the available adaptive features in the web-based learning environment.

JointZone without adaptivity: JointZone itself is a fully functional website. A good level of usability was established (see section 4.5) in order to make sure the site can still be used if the added intelligence is disabled (i.e if the user chooses not to log in). Hence, adaptivity was applied to an existing, fully functional web application.

Simplicity of the user model: Simplicity was emphasized in the design of the user modeling for JointZone. This is due the nature of the application, the usability is influenced by the speed of the network and computer processing power available to the user. Any process of intervention will be applied in real time. This can be seen as an intrusive and would introduce a delay to the users' normal interaction with the system. If the level of complexity in the application is high, the system will incur a longer delay and cause more frustration to the users. To avoid this in JointZone, the user model was kept as simple as possible.

Constraint on effort from domain expert: The development of JointZone required considerable effort from a medical practitioner to provide the domain expert knowledge. Due to the heavy demands of a full-time medical practice, the domain expert involved in the development of JointZone had limited time to spare to contribute to the design of the domain model for adaptation purposes. A methodology was identified to minimize the time and effort required from the domain expert in this work.

6.2 The Adaptation Model

Figure 6.1 shows the adaptation model of JointZone. It comprises the three essential building blocks for an adaptive system: a domain model, a user model and an adaptive layer. The *domain model* is derived from an offline process that draws its input from XML formatted content. The *user model* establishes dual-communication channels by providing user data to the adaptive layer during the adaptive decision making process. In turn, all changes to a user's status during an interaction session are fed back to update the user model. The *adaptive layer* is responsible for mapping user data to the domain model in the process of adapting information to users. It is achieved by JSP programming that involves if/else Java statements to make decisions on what links or content to be shown to the users. An example of this is shown below, the Java statements (<% ... %>) are embedded among the HTML codes in the JSP pages to provide different links and content based on the user's status:

```
<% //decide on query to use based on usergroup %>
<% if (usergroup.equals(”advanced”)){ %>
      <% query = queryExpert; %>
      <A href=”?usergroup=beginner”>Beginner</A>
      <A href=”?usergroup=intermediate”>Intermediate</A>
      <SPAN class = ”big”>Advanced</SPAN>
<% }else if(usergroup.equals(”beginner”)){ %>
      <% query = queryNovice; %>
      <SPAN class = ”big”>Beginner</SPAN>
      <A href=”?usergroup=intermediate”>Intermediate</A>
      <A href=”?usergroup=advanced”>Advanced</A>
<%}else if(usergroup.equals(”intermediate”)){ %>
      <% query = queryInt; %>
      <A href=”?usergroup=beginner”>Beginner</A>
      <SPAN class = ”big”>Intermediate</SPAN>
      <A href=”?usergroup=advanced”>Advanced</A>
<% } %>
```

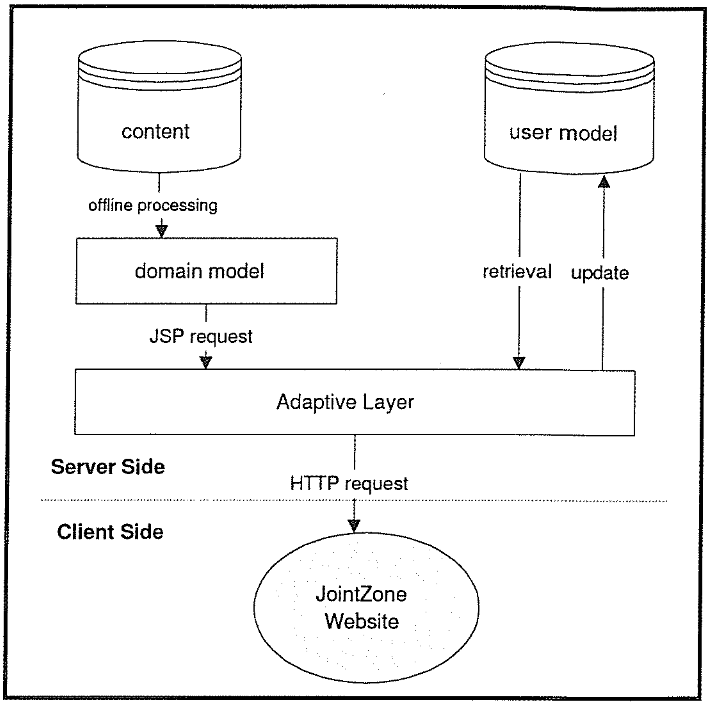


FIGURE 6.1: The adaptation model of JointZone

6.3 Domain Modeling of JointZone

This section explains how content was organized to make adaptation feasible in JointZone. The approach was adopted from the field of information retrieval where text processing is used to identify the semantics of the content without involving human effort. In the process, keywords were extracted automatically to be used as indexing terms for the documents. Indexing terms are (document) words whose semantics reflect the document's main themes, they are used to index or summarize a document (Baeze and Ribeiro 1999).

6.3.1 Text processing in domain modeling

The keyword extraction methods used produce both single word and bigram[1] indexing.

In the case of *single word* indexing, a medical dictionary (Dark 2000) was used to identify significant words in the documents which are domain dependant. In order to reduce the set of representative keywords, the documents were first parsed to eliminate stopwords such as articles (a, an), prepositions (in, of), conjunctions (and) and pronouns(he, she). Stemming was used to reduce distinct words to their grammatical roots. Each word in

[1] bigram, two consecutive words that occur together in a text

the remaining text was then checked with the dictionary, if it existed in the dictionary, it was chosen as an indexing term.

In terms of extracting *bigrams*, a statistical method called the Fisher Exact Test (Pedersen 1996) was used to extract dependent bigrams. A *dependent bigram* is one where two words occur together not purely by chance. A good example of this is the bigram - 'rheumatoid arthritis' as compared to the two words 'test taken' which occur together randomly. The Fisher Exact Test decides if a bigram (XY) is dependent based on the frequency of appearance of each word that constitutes the bigram (X, Y) in all documents in the domain. The test computes the frequency distribution of XY, $X\overline{Y}$, $\overline{X}Y$ and $\overline{XY}$. For example, in the bigram 'joint importantly', the variable X is used to denote the presence(X) or absence($\overline{X}$) of 'joint' in the first position of each bigram. Likewise, the variable Y is used to denote the presence(Y) or absence($\overline{Y}$) of 'importantly' in the second position of each bigram.

joint importantly	joint ?	? importantly
71	1384	2296
crystal arthritis	crystal ?	? arthritis
91	91	355

TABLE 6.1: A contingency table denoting the frequency of possible combinations of the variable values for bigram 'joint importantly' and 'crystal arthritis'.

As shown in table 6.1 above, the relationship of the frequency distribution decides the degree of dependence of the bigram. In this case, the first bigram 'joint importantly' will be rejected as a dependent bigram because both 'joint' and 'importantly' appear to be common variables to form other bigrams rather than 'joint importantly'. On the other hand, 'crystal arthritis' is accepted as a dependent bigram because the combination of crystal and arthritis as a bigram is significant since most appearances of the word 'crystal' are followed by the word 'arthritis'.

The bigrams or single words extracted as indexing terms were then stored as links with their respective URL in a linkbase known as a concept linkbase in JointZone.

As shown from the concept linkbase in Figure 6.2, each indexing term extracted from a document contributes to a link entry that contains:-

- the *id*, an auto-generated unique number for each entry.
- the *concept*, a keyword extracted from a section of the document through text processing as described in Section 6.3.1.
- the *context*, formulated from the structural layout of the document in which the keyword exists. For example, the entry with the title 'Bone Disease' has the context of 'Non-inflammatory Disorders in Rheumatic Disorders' because this title appears

under the subheading 'Non-inflammatory Disorders' which in turns comes under the heading of 'Rheumatic Disorders'.

- the *title*, referring to the title of the section where the keyword appears.
- the *url*, an address pointing to not just the document but specifically the section of the page where the keyword appears.

```
<link>
    <id>179</id>
    <concept>bone scan</concept>
    <context>Miscellaneous Disorders in Rheumatic Disorders</context>
    <title>Algodystrophy Reflex Sympathetic Dystrophy</title>
    <url>http://softly:8080/xml/algodystrophy.jsp#intro</url>
</link>
<link>
    <id>2156</id>
    <concept>Osteoporosis</concept>
    <context>Non-inflammatory Disorders in Rheumatic Disorders</context>
    <title>Bone Disease</title>
    <url>http://softly:8080/xml/bonedisease.jsp#Osteoporosis</url>
</link>
```

FIGURE 6.2: An example of link entries from the concept linkbase in JointZone

The use of these link entries, which is constructed from the conceptual representation (where an indexing term represents a concept) and the structural-based labeling (title, context, URL) of the content, made the content organization feasible. This creates an opportunity for adaptation since different link entries can be shown to different users. For example, more advanced users can be exposed to more concepts than novices (see section 6.5.1). At this stage in the development of the content, the domain expert needs only to identify different set of concepts for different groups of users rather than having to produce a prerequisite network of pages in the domain.

6.3.2 Accuracy

There is always a tradeoff in automating the process of domain modeling. In this case, there is a risk of compromising the accuracy with automation. In our experience, some of the concepts given by the domain expert did not map with any entry in the concept linkbase (the concept could be represented by a different term, i.e 'sciatica' is also called 'back pain') or alternatively they led to too many pages (too general terms, such as 'arthritis'). Hence, a lot of fine-tuning and changes were required by working closely with the domain expert to find the right set of concepts before the list was finalised and implemented in the application. This was to ensure more accurate pages are suggested based on a more precise set of concepts provided by the domain expert.

6.3.3 Scalability

The use of text processing has long been establised in information retrieval research to provide indexing terms for online text. However this work reflects a pioneering use of the method in educational adaptive hypermedia for organising and labelling content. This method promises a degree of scalability because it can be used on any domain. In short, the idea is transferable to any adaptive hypermedia system regardless of the type of content. The type of dictionary used is however dependent on the type of domain. In our case, a medical dictionary is used because it contains terms related to acronyms, jargon, theory, conventions, standards, institutions, projects, eponyms (i.e. 'Alzheimer's disease'), history, in fact anything to do with medicine or science. For a different domain such as computer science or history, a domain-specific or a general dictionary is perhaps more appropriate so that there is more scope for mapping words between the documents and the dictionary.

6.4 User Modeling in JointZone

6.4.1 Modeling the level of knowledge

In JointZone, we capture the domain knowledge levels of the user in order to map them to the various difficulty levels of the learning materials. The users were stereotyped into one of the following categories: expert, intermediate or beginner, upon their registration into the application. This online registration serves as a means to initialise the user model with the user's particulars such as first name, last name, email address, username and password (see in Appendix C Figure C.1). The categorization of user group is based on two questions asked during the online registration:

- Are you a medical professional, medical student or non-medical professional?
- How much do you know about Rheumatology? (none/ a little/ average/ a lot)

A heuristic categorization is produced based on the answers. Please see table 6.2:

Prior Knowledge / Status	Medical Professional	Medical Student	Non-medical Professional
none	intermediate	beginner	beginner
a little	intermediate	intermediate	beginner
average	expert	intermediate	beginner
a lot	expert	expert	beginner

TABLE 6.2: Heuristic Categorization of user group based on registration

However, this self-rating is not always accurate since users might not have a full understanding of their knowledge level in Rheumatology. For this reason, they are prompted to take an optional prior knowledge test (see in Appendix C Figure C.5) at an early stage in the application in order to make a more precise assumption of the users' knowledge level. In this test, users are required to answer ten questions concerning the general topic of Rheumatology. The categorization is based on their scores (see Table 6.3) and will overwrite the initial categorization in the registration.

Score	User Category
<30%	beginner
30%-70%	intermediate
>70%	expert

TABLE 6.3: User categorization based on the prior knowledge test

The system assumption of the user's knowledge can evolve as the user interacts with the application. This is based on their performance in the case studies. There are 10 case studies available for each of the user's knowledge level, e.g. beginner, intermediate and advanced level (see Section 4.3). A user's current knowledge is measured based on his or her performance in the case studies. Thresholds are set to promote users from one level to the next level in the knowledge state hierarchy (i.e from beginner to intermediate or from intermediate to advanced level). For example if a beginner achieves more than a 50% of the perfect score set for each of the 10 case studies in the beginner level, he/she will be promoted to the intermediate level in the user group hierarchy. The user will be informed of any change of status should any of this transfer of knowledge state occurs (see Figure 6.3).

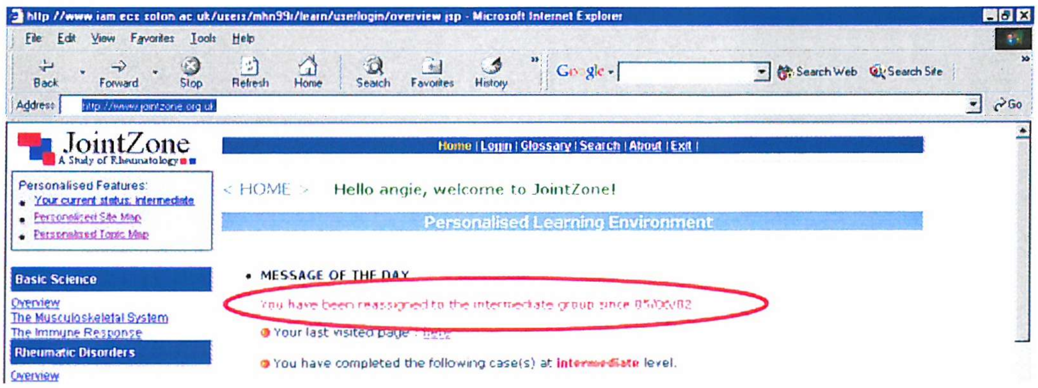


FIGURE 6.3: The message informing users the change of their user group status

6.4.2 Modeling browsing history

6.4.2.1 Previous work in modeling browsing history

A difficult problem faced by many adaptive hypermedia developers is how to identify whether a page has been read. A common but unreliable solution is to use the viewing of a page as an indicator that the page has been read and understood (e.g. InterBook

(Brusilovsky, Eklund, and Schwarz 1998)). This method is obviously inefficient as the student might only be surfing through the pages without paying much attention to the content. In MANIC (Stern and Woolf 2000), the system assumes a high studied rating for a page if a user spends an optimal amount of time on it. This optimal time which is based on the length of the content, is static for every user irrespective of their individual reading speed. However, psychological research has shown that there are 'astonishing differences in the rate of reading speed' among individuals (Romanes 1885). It has also been found that two individuals reading at the same speed can have different rates of comprehension (Huey 1908). Motivation for this research comes from users' unpredictable browsing behavior on the web, particularly the speed of reading web pages. Research has shown that users frequently skim-read web pages instead of reading them in detail (Horton, Taylor, Ignacio, and Hoft 1996). Studies have also shown that there is a general decline in the level of comprehension (especially in the recall of specific details) with faster reading as compared to reading at a normal speed (Dyson and Haselgrove 2000; McConkie, Rayner, and Wilson 1973; Poulton 1958). Hence the reading speed, the time spent and the level of understanding on each page varies among individuals.

6.4.2.2 Implementation of reading effort indexing

The modeling of browsing history in JointZone is achieved through an effort index, ranging from 0 to 100%, estimated for each page in the domain (Ng, Hall, Maier, and Armstrong 2002). This index is the system's estimation of the '*degree of effort spent*' by a user on each page. This is calculated by comparing the *display time* of a web page with an individual's *optimal reading time*. The optimal reading time for a page is identified for each user depending on the individual's *reading rate*, *comprehension rate* and *prior knowledge* of the domain. These user characteristics are obtained when they use the system for the first time. Before their first entry to the application (see in Appendix C Figure C.2), a user will be asked to complete a series of entry tests in the following sequence:

- a *reading speed test*, where the user's reading rate is captured in terms of the number of words read per minute. The reading time is recorded by means of a start and stop button on the web page (see in Appendix C Figure C.3).
- a *comprehension test*, consisting of six true or false questions on general ideas in the text used for the previous reading speed test. The comprehension test gives an indicative score of the user's comprehension rate (0-100%)(see in Appendix C Figure C.4).
- a *prior knowledge test*, consisting of ten multiple choice questions based on the general concept of the domain to give a measurement of the user's prior knowledge

(0-100%)(see see in Appendix C Figure C.5).

All measurements obtained from the three tests above are used to calculate the user's *effective reading speed* (Jackson and McClelland 1979). This index is commonly used in commercial products for speed-reading courses (TurboRead.com 2002; ReadingSoft.com 2000). In our work however, we have modified the equation by adding the factor of prior knowledge. As a result, we define effective reading speed as shown in Equation 6.1).

$$\text{Effective reading speed} = \text{reading rate} * \frac{1}{2}(\text{comprehension rate} + \text{prior knowledge}) \tag{6.1}$$

For example, assume a user, U1, can read at the speed of 200 *word-per-minute*. If he/she can comprehend 60% of the materials read and his/her prior knowledge of the domain is 50%, his/her effective reading speed (measured in term of *effective word-per-minute*, ewpm) is calculated as follows:-

$$\text{Effective reading speed for U1} = 200 * \frac{1}{2}(0.6 + 0.5) = 110 \text{ ewpm}$$

This effective reading speed is used throughout the browsing session. The *optimal reading time*, optimalTime, for any page in the domain is calculated in real time based on the page length and the effective reading speed (Equation 6.2). The *effort index* on each page is then estimated using a Gaussian function by comparing the *actual time spent*, x, on a page with the optimal reading time (Equation 6.3). If 'x' approaches the optimal reading time, a high effort index is assumed (see Figure 6.4) for that page. The σ is the standard deviation set heuristically for the Gaussian function based on a set of experimental data gathered from the users.

$$\text{optimalTime} = \frac{\text{total number of words in the page}}{\text{Effective reading speed}} \tag{6.2}$$

$$\text{Effort index estimation}, \mathbf{G}(x, optimalTime) = \exp(\frac{-(x - \text{optimalTime})^2}{2\sigma^2}), \text{where } \sigma = 1.23 \tag{6.3}$$

Taking the previous example, if U1 has an effective reading speed of 110 ewpm, and he/she spends 3 minutes reading a page, y, of 759 words length, his/her optimal reading time for that page is calculated in real time by the system as followed.

$$\text{optimal reading time for user U1 on page y} = \frac{759 \text{ words}}{110 \text{ ewpm}} = 6.9 \text{ minutes}$$

This optimal reading time is compared with the actual time spent, x, based on Equation 6.3 to give an effort index. For example, if x = 3 minutes, a low effort index is assumed.

$$\text{effort index for user U1 on page y} = \exp(-0.33(3 - 6.9)^2) = 0.6\%$$

But if user U1 spends a longer time on the page, say x = 6 minutes, a high effort index is achieved.

$$\text{effort index for user U1 on page y} = \exp(-0.33(6 - 6.9)^2) = 76.5\%$$

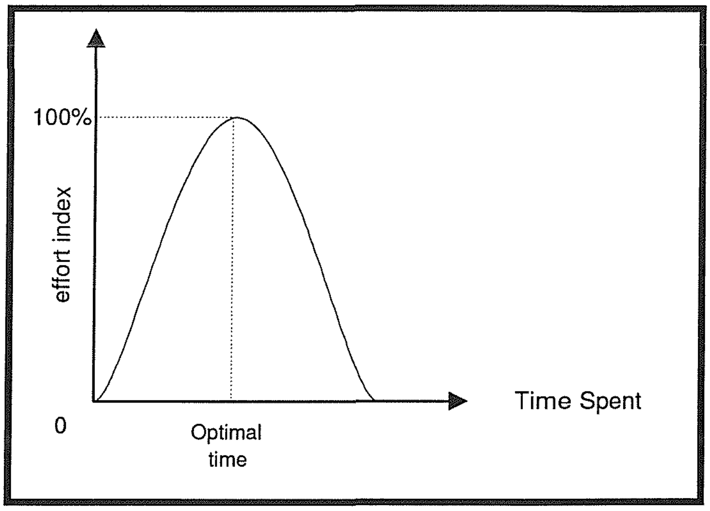


FIGURE 6.4: The Gaussian graph for the effort index estimation based on Equation 6.3

Hence by using the Gaussian function, a comparison can be done between the optimal reading time and the actual reading time in order to estimate the effort index of a student on a page. This bell-shaped function is different for one individual compared to another since all users will have dissimilar optimal reading time on a page. The function is also capable of performing non-linear comparison. For example, as the actual time spent approaches the optimal reading time, a higher effort index will be estimated. On the other hand, the more the actual reading time exceeds the optimal reading time, the lower the effort index would be estimated. This, presumably, covers the possibility where the users might have left the screen and not actually reading its content.

6.4.2.3 Validation test

A validation test (Ng, Hall, Maier, and Armstrong 2002) was carried out to study the correlation between the effort index and the users understanding of the content itself. Thirty subjects took part in the evaluation. Prior to the experiment, all users were instructed to complete a series of entry tests (as mentioned in Section 6.4.2.2) to capture their individual effective reading speed. The analysis for thirty users shows a mean effective reading speed of 116 word/min (sd = 58.74), a mean prior knowledge of 30.67% (sd = 15.52) and a mean comprehension rate of 63% (sd = 15.93).

In the main experiment, they were asked to read a page (length = 443 words)(see in Appendix D Figure D.1) of the same domain as the page used in the reading speed test. This is followed by a performance test to examine how much they have understood the page. The test contained five multiple-choice questions (see Figure D.2). The type of questions used were concerned with recalling some important aspects in the text (main factual type)(Dyson and Haselgrove 2000). All users spent an average of 3.19 minutes reading the page (sd = 1.12 minutes). The effort index for each user was estimated by the system using Equation 6.3. This effort index was then compared with the score of the performance test. The Pearson correlation test showed a *significant* correlation between the effort index and the performance test ($r = 0.521$, $p = 0.003$). The performance score was also compared with a separate calculation of effort index using a standard optimal reading time - 2.25 minute using the average on-screen reading rate of 200 words-per-minute. The Pearson correlation test shows a *non-significant* correlation of 0.056 ($p = 0.767$). Hence, the validation test indicated that each user has a different optimal reading time, which gives a better approximation of the users understanding of the domain.

6.4.2.4 Discussion

How to ensure a page is indeed 'read' by the user? One problem still exists. It is difficult to determine if a user has indeed read a page when it is displayed on the screen. To tackle this, a *heuristic cutoff point* was used to give a zero effort index for cases where the display time falls below eight seconds or three times the optimal reading time.

How is the difficulty of the content reflected in the effective reading speed? The difficulty level of the domain is incorporated in the prior knowledge factor that contributes to the effective reading speed in Equation 6.1, so the effective reading speed of a user will be tuned by their prior knowledge in the content. For example, a domain novice will get a lower effective reading speed compared to an expert (if both have the same reading rate). Hence, the same page will require longer optimal reading time for the novice than the expert. Following from this, a great advantage of using the individual optimal reading times was that it enabled us to skew the effort index based on a user's prior knowledge so a good student who skims a page will gain a higher effort index (with relatively lower optimal reading time) as compared to a novice student who spent the same amount of time on the page.

What if the user has not taken the reading test? A default effective reading speed of 200 ewpm (ReadingSoft.com 2000) is assigned to the users if the reading speed test is not taken.

A validated alternative? The individual effective reading speed used in calculating the effort index on the pages has provided a relatively good approximation for judging how well a page has been read. However, the cognitive issues of measuring the user's understanding have yet to be addressed. Hence, this work cannot claim that the effort index completely represents a user's understanding of the text on the page. There are more accurate methods, such as giving users a comprehension test for *every* page that they have read, but this would be very intrusive to the user's normal interaction with the application. This work has provided a practical method of estimating reading effort with some accuracy tradeoff. The validation test in the previous section has shown that this method gives comparatively more accurate approximation than existing methods as mentioned in section 6.4.2.1. With this encouraging result, the effort index was used to implement the history-based link annotation in JointZone, which is described in the following section.

6.5 Adaptive Approach in JointZone

6.5.1 Knowledge-based link-hiding

Knowledge-based link-hiding is made possible by the provision of a linkbase as mentioned in section 6.3.1. Link hiding was implemented by manipulating the number of links displayed according to the user's knowledge level. In this case, advanced users are given a wider range of documents than those with less knowledge. For example, for the topic of 'tennis elbow', advanced students are provided with access to documents about four concepts: 'tennis elbow, epicondylitis, enthesis and enthesitis' from the linkbase while intermediate students are directed to only two concepts namely 'tennis elbow and epicondylitis'. Beginners are simply shown the single concept of 'tennis elbow' (see Figure 6.5). The domain expert identified these three sets of concepts for each case study, which was an easier task for them compared to delivering a prerequisite network of documents [see section 5.6]. However, in order to be consistent with the philosophy of an unobtrusive learning environment, there is no restriction for any user group should they wish to investigate further, i.e. in the default page that shows a list of documents for beginners, there is an optional link that is displayed at the same time to navigate to the document list that is meant for intermediate or advanced level.

6.5.2 History-based link-annotation

The effort index calculated as described in section 6.4.2.2 was used to implement the history-based link annotation in JointZone. Whenever a user visits a page, the system

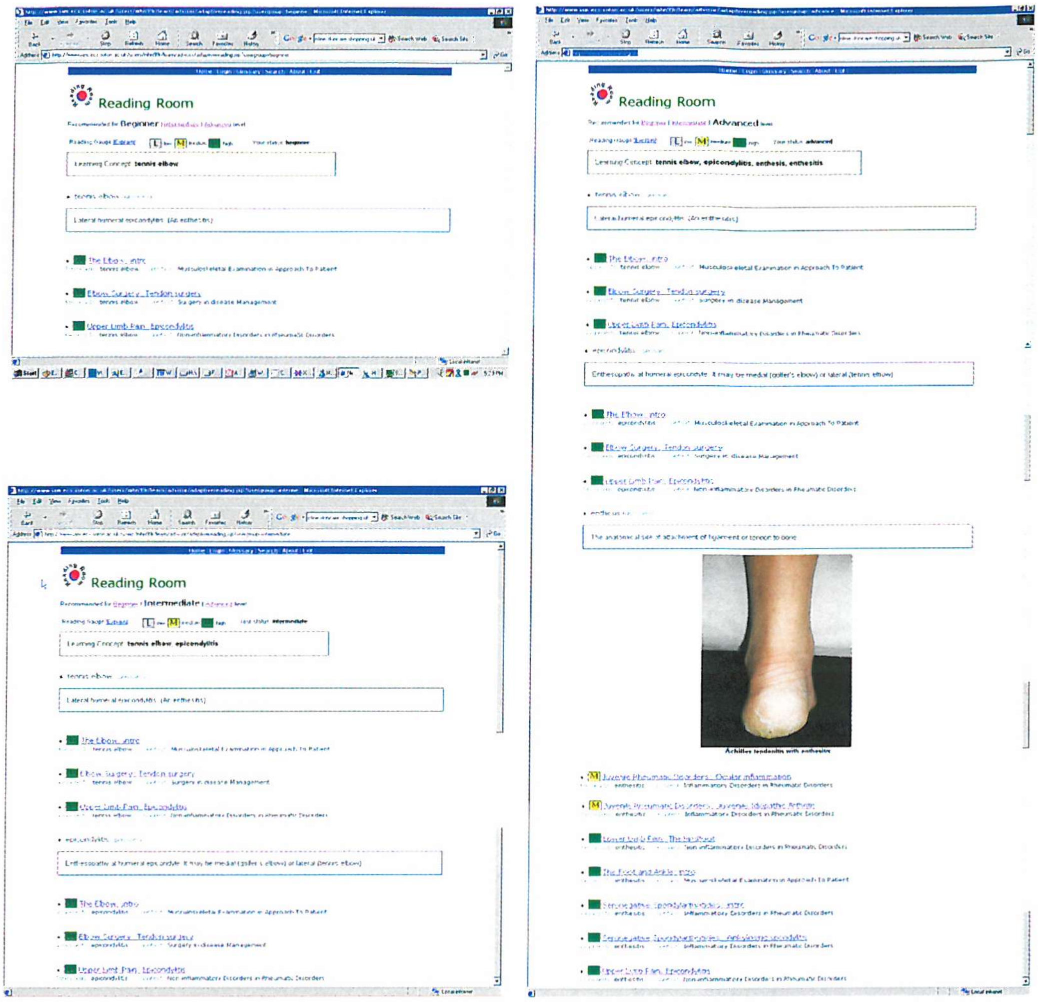


FIGURE 6.5: Application of knowledge-based link hiding in a personalized reading room: different list of reading concepts and pages for beginner (top left), intermediate (bottom left) and advanced level (right)

calculated the effort index and stored the value in the user model. As the user visits more pages, the subsequent reading effort index for each page is estimated and stored. This record of user model attributes are then used to construct reading gauge - a visual representation to the users indicating how much they have read each individual page (see Figure 6.6). The reading gauge consists of one of the three values:

- *Low* - effort index 0 -30%
- *Medium* - effort index 30%-70%
- *High* - effort index $\geq$ 70%

As shown in Figure 6.6 the grey icon with a letter 'L' indicates low reading effort index, the yellow icon with a letter 'M' indicates medium reading effort index and the green icon with a letter 'H' indicates high reading effort. This provides the history-based link

FIGURE 6.6: Application of history-based link annotation in JointZone: an example of a set of links annotated by reading gauge which indicates high (H, green), medium (M, yellow) and low (L, grey) effort index

annotation which gives users additional information on a page and help them to focus on pages they have read very little or not at all.

6.6 Adaptive Features in JointZone

JointZone offers the user some adaptive features based on the knowledge-based link hiding and the history-based link annotation as described in Section 6.5. Each feature is explained and illustrated in the following sections.

6.6.1 Personalized Site Map

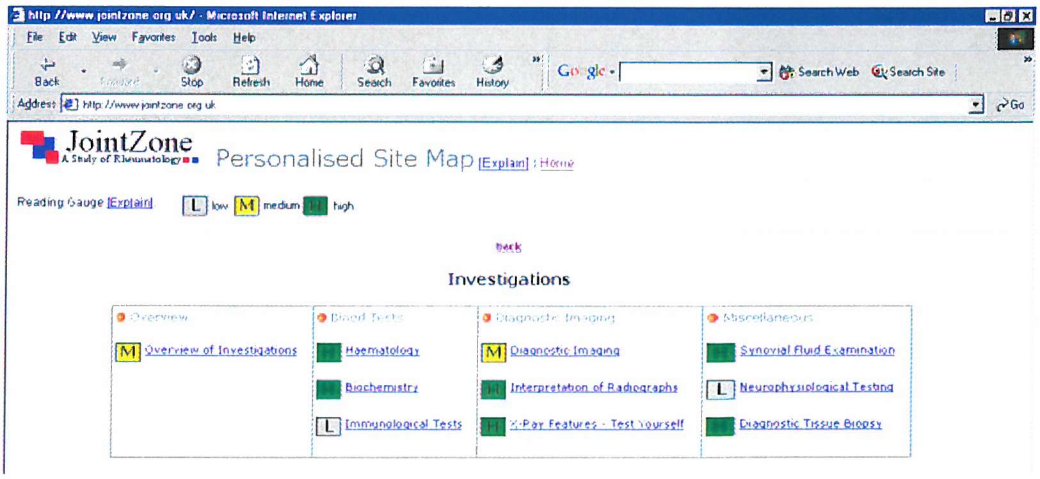


FIGURE 6.7: A screen shot of the personalized site map where history-based link annotation can be seen.

The site map in JointZone presents links to all documents that appear on the site. It is personalized by the set of links that are made adaptive to the individual's browsing history using the history-based link annotation. As can be seen in figure 6.7, each document title is marked by a reading gauge icon to inform the user how much they have read the page before. This site map acts as a navigation support mechanism to give users a quick overview of the domain with relation to pages they have read or not read.

6.6.2 Personalized Topic Map

The adaptive mechanism of the personalized topic map is based on the user's browsing history, domain knowledge level and learning goal (a topic of learning, e.g. 'gout'). A combination of the history-based link annotation and knowledge-based link hiding is used in this case.

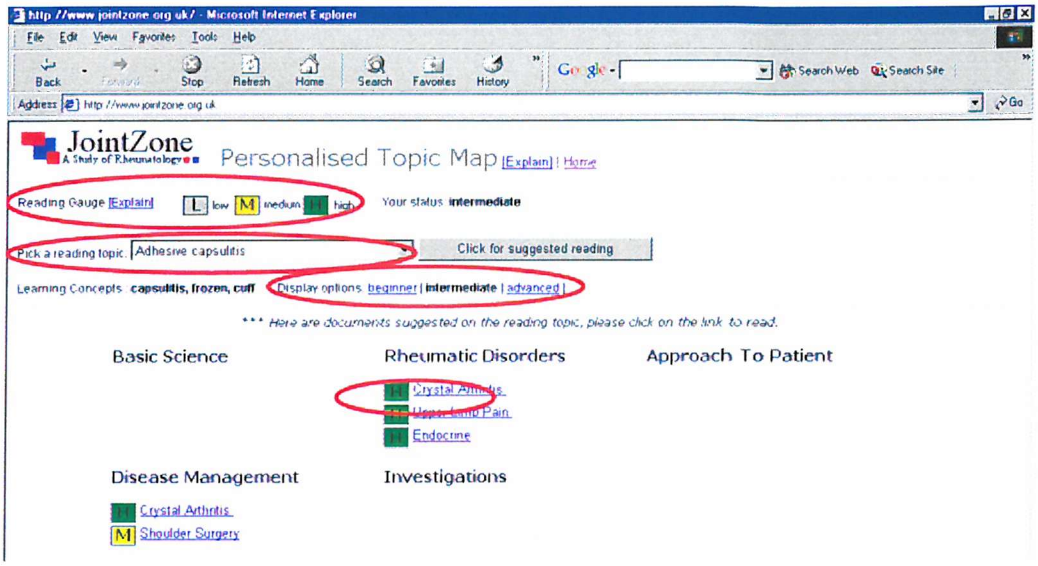


FIGURE 6.8: A screen shot of the personalized topic map with the combination of knowledge-based link hiding and history-based link annotation

Users need to manually select a learning topic (short term goal) from a pull-down menu, for example 'adhesive capsulitis' (Figure 6.8). The topic map will then show links to documents about adhesive capsulitis that are relevant to the user's status as an intermediate user. At the same time, the history-based link annotation provides extra feedback to the user on which documents he or she has studied previously.

6.6.3 Adaptive Reading Room

The adaptive reading room appears at the end of every case study on the site (see figure 6.9). Its purpose is to provide an opportunity for further reading in order to find out more in depth information on a topic or concepts related to the case study.

Again, knowledge-based link hiding and the history-based link annotation are used to suggest a personalized list of documents for further reading on the site. The number of documents shown reflects the users' status and each link is marked by the reading gauge icon.

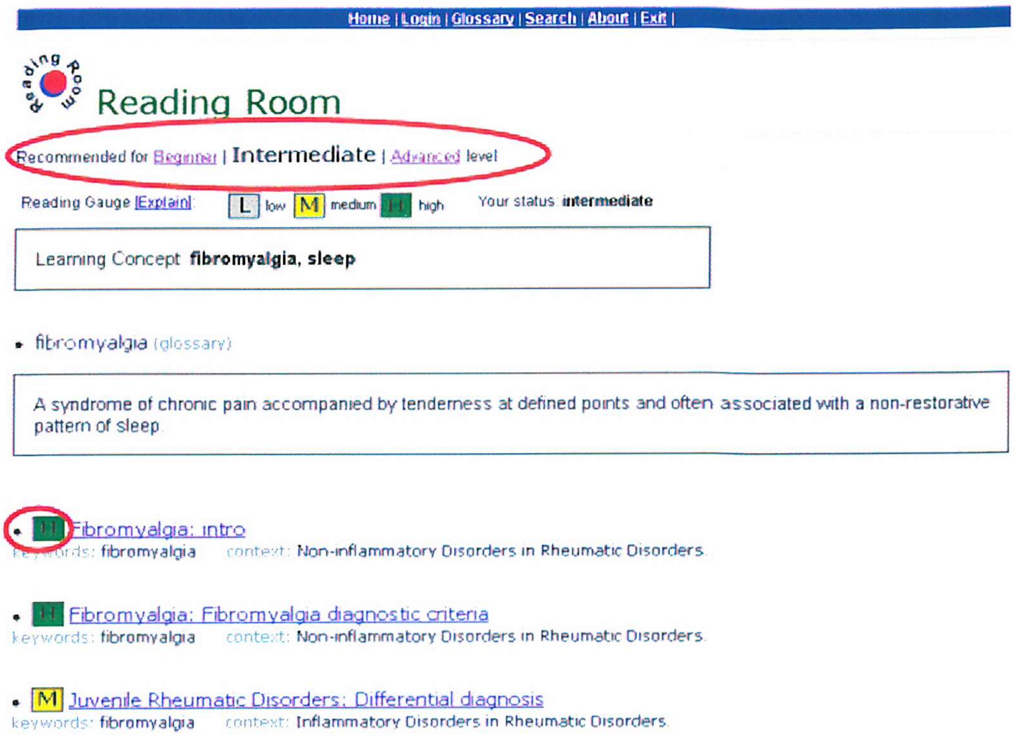


FIGURE 6.9: A screen shot of the adaptive reading room

6.6.4 Personalized Messages

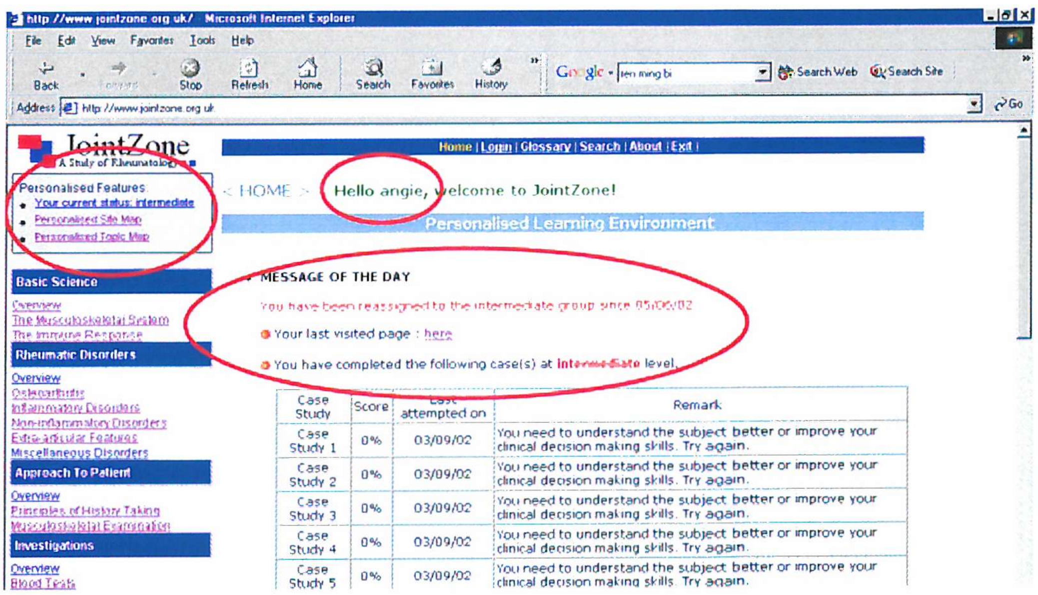


FIGURE 6.10: The personalized message on the 'Home' page

Personalized messages appear mainly on the 'Home' page (see figure 6.10) where a user first enters the site after the log in procedure. This page includes a personal greeting to the individual to provide an atmosphere of a personalized learning environment. The messages inform the user of their current status (i.e. a promotion to the next level in the user group hierarchy) and also provides feedback on their previous visit, including a pointer to the last page they have visited. The feedback also provides a detailed account of the case studies they have completed. From this, users can decide whether they should retry the completed case study(if they have performed poorly), follow further reading suggestions on a topic, or proceed to other case studies.

6.6.5 Personalized User Report

The personalized user report gives a summary of the user's profile that contains the individual's name, email, the user status and the date of registration (Figure 6.11). It is also a record of the user's performances in the case studies they have attempted. This includes a score, the number of previous attempts and a remark from the domain expert for each attempted case study. Towards the end of the report, a summary of current reading activities is given in terms of the percentage of reading coverage the user has completed in the domain. From a pedagogical perspective, this user report provides feedback to both users and lecturers about a user's learning progress in the domain.

6.6.6 Adaptive Assignment of Case Studies

In JointZone, the system assigns case studies adaptively to the user's knowledge level. This is indicated by the adaptive link annotation on the table of contents (figure 6.12). Users are encouraged to try out the recommended level of case studies but nevertheless they are not prevented from trying non-recommended levels.

6.7 Discussion

JointZone has demonstrated the methodology of providing a personalised learning experience in a web-based medical learning application. Instead of building an AH system right from the start, as preferred by most of the previous work in AH (Section 5.5), our approach is more towards integrating adaptive elements into an existing, fully functional web application. The quality of the content delivered is the chief concern of the domain expert instead of just aiming to make the application adaptive. Hence the objective of this work is to integrate various adaptive features seamlessly into the regular functionality of JointZone, imposing the least intrusion upon the normal interaction between the user and the application.

As shown in Section 6.6, the adaptive features in JointZone are made available as an added value on top of the existing functional web application. They offer adaptive navigational support in a web-based environment that promote self-exploratory learning.

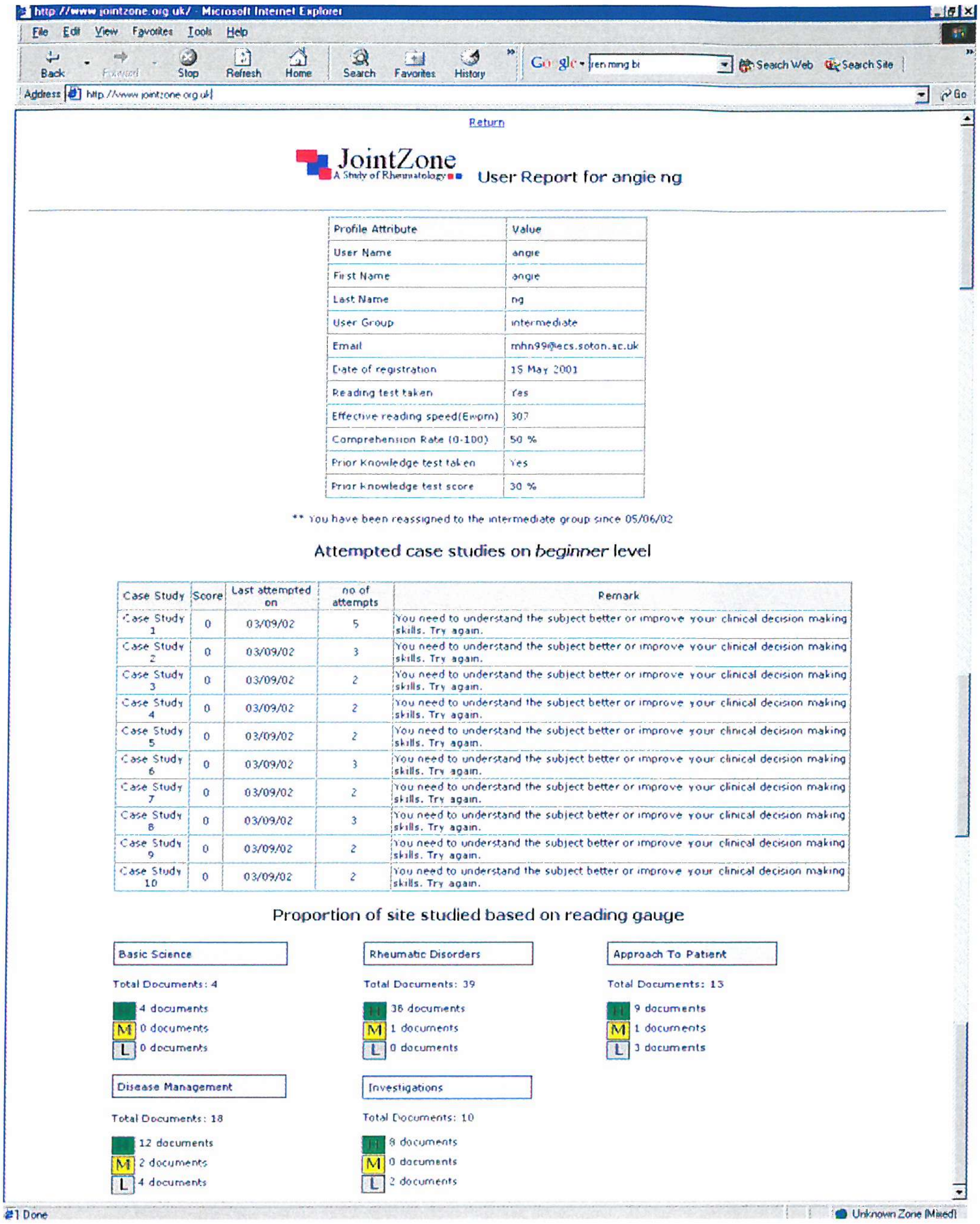


FIGURE 6.11: The personalized user report

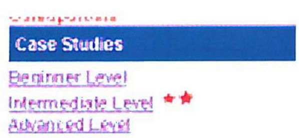


FIGURE 6.12: Adaptive assignment of case study: A screen shot of the table of content showing the annotated links for case study, in this case, the user is prompted to the intermediate level

Adaptive features in JointZone such as the personalised site map, the personalised topic map and the adaptive reading room promote self-exploratory learning and offer learner control in the learning process (see Section 3.2). Hence, the nature of adaptivity in JointZone is applied in the context of browsing aid, in contrast with the task-based adaptation which concentrates on adapting users to specific learning concepts, as reflected in the curriculum sequencing in MANIC, Interbook, AHA! and ELM-ART.

The user model of JointZone is a combination of the stereotype model (based on the assignment of user groups) and the individual model (based on browsing history). This is very different from most of the AH systems (e.g. ELM-ART, MANIC, INTERBOOK and AHA!, see Section 5.5) that revolve heavily around an overlay user model that closely matches the domain of an application. The core of adaptivity in JointZone revolves around a simple user model. The stereotype modeling of students' knowledge is explicit, based on a prior knowledge questionnaire and the update rules to this attribute is based on students' performance on the case studies. The individual modeling of browsing history is based on reading effort index which is the novelty of this work. Our method has been validated against the current methods used in the AH community and it is found to give comparatively more accurate approximation than existing methods (see Section 6.4.2.3).

On the other hand, the semi-automation of domain modeling in JointZone using keyword representation and concept matching (see Section 6.3) has freed the domain expert from taxing involvement in the work of organising the domain for adaptation (i.e. constructing a prerequisite based network). If the development of JointZone followed the conventional adaptive approach as demonstrated by AHA!, ISIS-Tutor, Interbook, ELM-ART, PLS or MANIC, the domain expert would need to sequence the learning materials into prerequisite and outcome concepts, define the conditions for displaying each node and decide the update rules for each visited node. This added complexity can become a problem for certain AH application development due to the constraint of obtaining the expert involvement. Under these circumstances, JointZone has demonstrated an alternative method that is simpler and much more manageable for the domain expert.

6.8 Summary

This chapter describes how adaptivity was integrated into a fully functional website - namely JointZone. The objective of this work was to keep the user model as simple as possible and to minimize the involvement of the domain expert. The domain modeling of JointZone was achieved through conceptual representation based on document indexing terms and the structural-based labeling of the content. The user model of JointZone focused on modeling the user's knowledge level and their browsing history. Two adaptive approaches were taken, namely knowledge-level link hiding and history-based link annotation. The chapter ends with examples of the adaptive features implemented in

JointZone. The next chapter will present an evaluation on the adaptive features that were implemented in this chapter.

Chapter 7

Evaluation

7.1 Introduction

This work has presented an adaptive learning environment that is based on the novel idea of using individual's reading speed to estimate their reading effort index for the provision of adaptive history-based link annotation. This method has been proved to be more effective than existing methods in capturing a page reading value as shown in Section 6.4.2.3. Another contribution of this work is its domain modeling approach, particularly within the educational AH context, that requires a lesser involvement from the domain expert. Contents can be easily organised through a concepts linkbase for the provision of adaptive knowledge-based link hiding (see Section 6.3.1). Both the adaptive history- based link annotation and the adaptive knowledge-based link hiding have been employed in various personalised features in JointZone such as the personalised site map, the personalised topic map and the adaptive reading room. This chapter will present an evaluation of JointZone on these personalised features to study the impact of the adaptive techniques on the aspect of navigation and learning within JointZone.

7.2 Evaluation Approach of JointZone

The evaluation was performed with a group of medical students from the University of Southampton. The main aim was to assess the effectiveness of the application of adaptive techniques, both the history-based link annotation and the knowledge-based link hiding, in the personalised features of the JointZone application. The evaluation approach adopted was from the layered evaluation proposed by (Karagiannidis, Sampson, and Brusilovsky 2001). This approach suggests two layers of assessment:

- Interaction Assessment Layer - This assesses if the conclusion drawn by the system concerning characteristics of user-computer interaction is valid. For example, is the system's assumption of the user's knowledge level accurate?

- Adaptation Decision Layer - This assesses if the adaptation decision is valid and meaningful, for selected system assumptions. For example, is the set of links presented based on the user model meaningful to the user?

The benefits of this layered approach can be seen when adaptation is unsuccessful since troubleshooting can be done in both layers. The layered approach gives two possibilities for adaptation failure. Firstly, it can be the case that the adaptation decisions are reasonable, but they are based on incorrect system assumptions; or that the system assumptions are correct but the adaptation decision is not meaningful (Brusilovsky, Karagiannidis, and Sampson 2001).

Therefore, the rationale behind the evaluation on JointZone was essentially two-fold: first, finding out whether the system makes a correct assessment of or assumption about the user, i.e. their current knowledge level and secondly, finding out whether the adaptive features are meaningful to users. The result of this evaluation has provided some answers to the following hypothesis:

- The adaptive features *facilitate the process of learning in JointZone by reducing the time taken to look for materials on the website and increasing the speed of navigation.*

- The adaptive features *improve learning in JointZone in comparison to learning without the presence of any adaptive mechanism.*

7.3 Subject Description

A total of 36 subjects took part in this experiment. They were divided randomly into two groups: the first group, G1, acted as the experimental group and the second group, G2, served as the control group.

The distribution of the subjects is shown in Table 7.1. The subjects were medical students from year 1 to year 5 and they were randomly assigned into G1 and G2. Both groups had the same average of prior knowledge and this was verified by an independent t-test [1] (t = 0.298, p = 0.768, insignificant). In terms of gender distribution, there were 16 females in G1 and 10 in G2, both groups had 5 male subjects each. With respect to computer background, G1 had 16 subjects who use the computer every day for internet or email checking, and six who use the computer once or twice a week. In G2, 14 subjects use the computer everyday and one, once or twice a week (see Table 7.2).

[1] A parametric test used for experimental designs with two conditions testing one independent variable, when different subjects are doing the two conditions (Greene and D'Oliveira 1982).

Group	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Average Prior Knowledge
G1	12	4	3	2	0	21	51.4%
G2	7	3	3	0	2	15	50%

TABLE 7.1: The distribution of subjects in the experiment according to their year of study and the groups average scores on the prior knowledge test.

Group	Gender		Usage frequency for internet or email	
	Male	Female	Everyday	Once/twice a week
G1	5	16	15	6
G2	5	10	14	1

TABLE 7.2: The distribution of subjects in the experiment according to their gender and the usage frequency of the internet or email.

7.4 Methods of Result Gathering and Analysis

In terms of results gathering, the paper-based pre- and post-tests set by a Rheumatology Consultant, Dr. Ray Armstrong (see Appendix E) were used. The difference between the pre-tests score and the post-tests score was used to assess the amount of knowledge acquired by the students. This variable is termed 'learning performance' in this evaluation. A software log was used to capture the time taken and the number of navigation steps required to complete a task. In terms of analysis, the results were grouped into users' objective and subjective feedback respectively. The subjective feedback was based on the users' opinions collected from the questionnaire in the experiment whereas the objective feedback was based on the dependent factors such as time spent, learning performance and navigational steps. Statistical analysis (Greene and D'Oliveira 1982; Foster 2001) was used to validate the results gained from the experiment.

7.5 Experimental Designs and Results

Two separate lists of tasks were assigned to the subjects in groups 1 and 2 respectively in the experiment (see tasks for G1 in Appendix E, from Figure E.1 to Figure E.6, and tasks for G2 from Figure E.7 to Figure E.11). A summary of the tasks and their purposes is listed as follows:

- *Task 0*: To complete a pre-test, log in and complete online entry tests to build up the initial user model.
- *Task 1*: To explore the usefulness of the topic map by comparing it with free browsing using the table of contents.

- *Task 2*: To study the effectiveness of adaptive history-based link annotation when applied to the personalised topic map.
- *Task 3*: To study the user's attitude towards the personalised site map by comparing it with the table of contents.
- *Task 4*: To study the accuracy of the system decision-making in assigning the difficulty level of case study.
- *Task 5*: To study the effectiveness of adaptive knowledge-based link hiding when applied to the adaptive reading room.

7.5.1 Task 0: Pre-test and Log in

The same pre-test for Task 1 and Task 2 was given to both groups before the experiment to assess their knowledge level (see in Appendix E, Figure E.12 and Figure E.13). Both groups were then prompted to login to two different versions of the web application. Once they were logged in, the subjects were asked to complete an online reading speed test and a prior knowledge test to build up their initial user model (see section 6.4).

7.5.2 Task 1: To explore the usefulness of the topic map by comparing it with free browsing using the table of contents

Group 1	Group 2
Use a non-personalised topic map to answer 10 questions on the topic of 'Psoriatic Arthritis'.	Use the table of contents (free browsing) for the same task.

TABLE 7.3: Task 1 - Allocation of users in the comparison between the topic map and the table of contents

Purpose: The purpose of Task 1 was to assess the significance of a baseline topic map (without any adaptive technique) in learning and information access. Task allocation for both groups is shown in Table 7.3

Hypothesis 1: -

H_1 = The *time taken* to complete a task is significantly reduced by the topic map as compared with the table of contents.

H_o = The *time taken* to complete a task is *not* significantly reduced by the topic map as compared with the table of contents.

(Note: H_1 is the *experimental hypothesis* - the prediction of the expected result from an experiment (Greene and D'Oliveira 1982). H_o is the *null hypothesis* - data resulting from the experiment are not as predicted by the experimental hypothesis.

They are chance fluctuations in people's performance due to the effect of other unknown variables (Greene and D'Oliveira 1982).)

Hypothesis 2: -

H_1 = The number of *navigational steps* is statistically lower by using the topic map as compared with the table of contents.

H_o = The number of *navigational steps* is *not* statistically lower by using the topic map as compared with the table of contents.

Hypothesis 3: -

H_1 = The *learning performance* is statistically higher using the topic map as compared with the table of contents.

H_o = The *learning performance* is *not* statistically higher using the topic map as compared with the table of contents.

Result for Task 1: Based on the one-tailed independent t-test as summarised in Table 7.4 and Figure 7.1, the null hypotheses for Hypotheses 1 and 2 were rejected indicating that the topic map has significantly reduced the time taken to complete a task and the navigational steps required. The rejection of null hypothesis 3 also demonstrates that the availability of the topic map has significantly improved learning performance.

Learning Factors (Average Feedback)	Experiment Conditions		Independent t-test (Equal variance assumed)
	Topic Map	table of contents	
Time taken to complete task (minutes)	$13.8^{\dagger}$	22.4	t = 3.02, p = 0.004***
Learning performance (-10 to 10)	$7.69^{\dagger}$	4.9	t = -2.65, p = 0.008**
Navigation steps (average)	$6.3^{\dagger}$	21.9	t = 3.11, p = 0.004***

** Statistically significant at the 5% level, *** Statistically significant at the 1% level,
† Best result

TABLE 7.4: Statistical summary of the comparison between the topic map and the table of contents

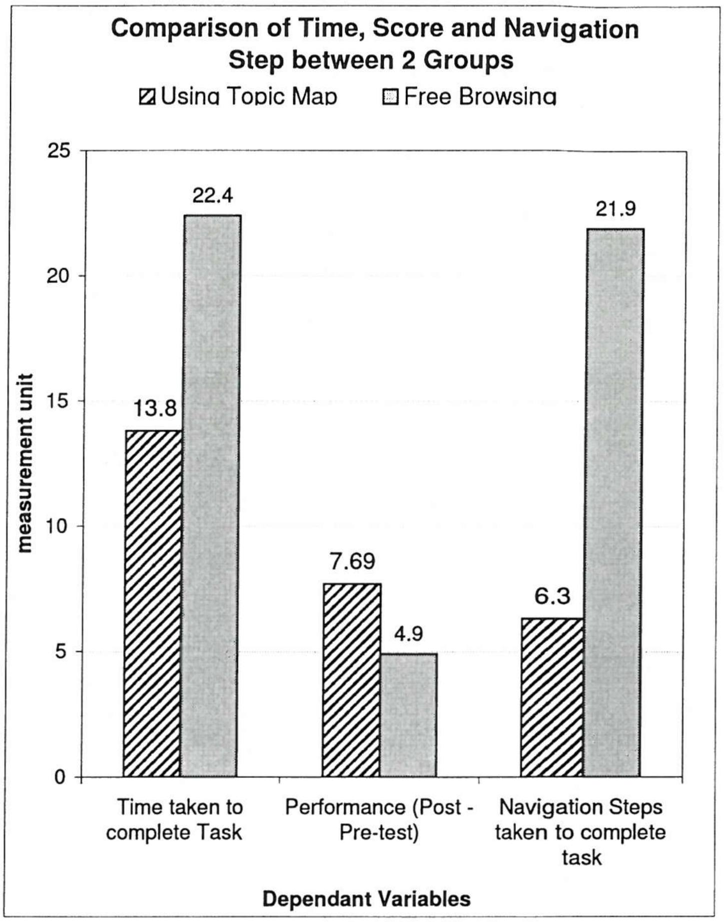


FIGURE 7.1: The comparison of time, performance and navigation steps between the use of the topic map and the table of contents.

7.5.3 Task 2 - To study the effectiveness of adaptive history-based link annotation when applied to the personalised topic map

Group 1	Group 2
Use the personalised topic map to answer 10 questions on the topic of 'Rheumatoid Arthritis'	Use the non-personalised topic map for the same task
with adaptive history-based link annotation	*without* adaptive history-based link annotation

TABLE 7.5: Task 2- The allocation of users in the comparison between the personalised topic map and the non-personalised topic map

Purpose: The purpose of Task 2 was to assess the significance of a personalised topic map[2] in learning and information access by comparing it with a non-personalised topic map (one without adaptive link annotation). Task allocation for both groups is shown in Table 7.5.

Hypothesis 4: -
H_1 = The *time taken* to complete a task is significantly reduced by using the personalised topic map as compared with the non-personalised topic map.
H_o = The *time taken* to complete a task is *not* significantly reduced by using the personalised topic map as compared with the non-personalised topic map.

Hypothesis 5: -
H_1 = The number of *navigation steps* is statistically lower by using the personalised topic map as compared with the non-personalised topic map.
H_o = The number of *navigation steps* is *not* statistically lower by using the personalised topic map as compared with the non-personalised topic map.

Hypothesis 6: -
H_1 = The *learning performance* is statistically higher in the group which used the personalised topic map as compared with the non-personalised topic map.
H_o = The *learning performance* is *not* statistically higher in the group which used the personalised topic map as compared with the non-personalised topic map.

Result for Task 2: Based on the one-tailed independent t-test as shown in Table 7.6, the null hypothesis for Hypothesis 5 was rejected which indicates that the reduction in the number of navigational steps using the personalised topic map (with the adaptive link annotation) is statistically significant as compared with the non-personalised topic map (without the adaptive link annotation). However, the null hypotheses for Hypotheses 4 and 6 were accepted to indicate that the personalised topic map does not reduce the time taken to complete a task and does not make any significant difference in terms of the learning performance in this task.

Comments: Figure 7.2 shows that the integration of personalized features in the topic map did not result in any statistically significant improvement in terms of the time factor or of learning performance. However, it did significantly reduce the number of navigational steps required to complete the learning task although the time taken was not affected by this reduction of navigational steps. A closer study of the log revealed the possibility that the group using the personalized features spent more time on each individual page, focusing on fewer pages; whereas the group without personalized features had to browse through more pages, spending less time on individual pages.

[2]Personalized topic map shows *certain* pages in JointZone that are related to a selected reading topic. For details see Section 6.6.1

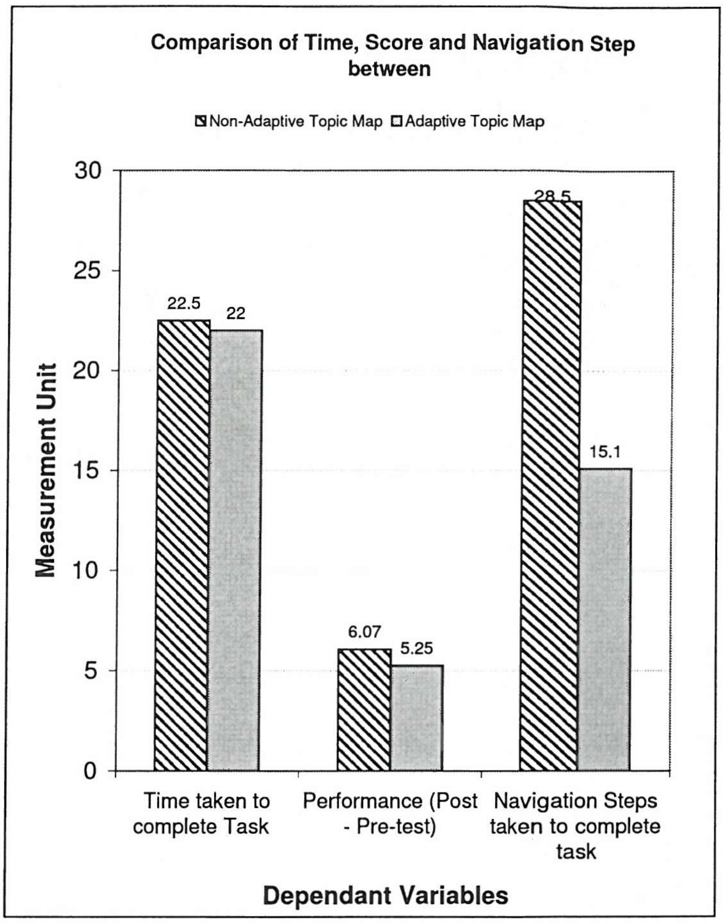


FIGURE 7.2: The comparison of time, performance and navigation steps between using personalised topic map and non-personalised topic map

Learning Factors (Average Feedback)	Experiment Conditions		Independent t-test (Equal variance assumed)
	Non-adaptive Topic Map	Adaptive Topic Map	
Time taken to complete task (minutes)	22.5	22	t = 0.107, p = 0.458 (insignificant)
Learning performance (-10 to 10)	6.07	5.25	t = 1.045,p = 0.154 (insignificant)
Navigation steps (average)	28.5	15.1	t = 2.271, p = 0.018**

** Statistically significant at the 5% level

TABLE 7.6: Statistical summary of the effect of personalization in topic map

7.5.4 Task 3 - To study the user's attitude towards the personalised site map by comparing it with the table of contents

Group 1	Group 2
Navigate around the web site using personalized site map and make a comparison with the table of contents. Answer questionnaires	same as group 1

TABLE 7.7: Task 3- The allocation of users in the comparison between the personalised site map and the table of contents

Purpose: The purpose of Task 3 was to acquire the user's subjective feedback on the personalised site map[3] and in particularly to study the acceptance by the user of the history-based link annotation in the personalised site map. Each group was allocated the same task as shown in Table 7.7. The users were given three questions by which to state their opinions at the end of this task (see in Appendix E, Figure E.5 and Figure E.6).

Hypothesis 7: -

H_1 = Users prefer using the personalized site map than the table of contents.

H_o = Users express *no* preference between using the personalized site map and the table of contents.

Hypothesis 8: -

H_1 = The adaptive history-based link annotation (reading gauge) is helpful in the personalised site map.

H_o = The reading gauge is *not* helpful in the personalised site map.

Hypothesis 9: -

H_1 = The personalised site map is useful in navigation.

H_o = The personalised site map is *not* useful in navigation.

Result for Task 3: Based on the chi-square test[4] as shown in Table 7.8, the null hypothesis for Hypothesis 7 is accepted which indicates that there is no user preference between using the personalised site map and the table of contents. However, the null hypotheses for Hypotheses 8 and 9 were rejected, indicating that a statistically significant number of subjects found the personalised site map useful and the reading gauge (the history-based adaptive link annotation) helpful.

[3]Personalized site map shows *all* pages in JointZone for navigation support in free browsing. For details see Section 6.6.2

[4]Use for making predictions about how many different subjects will fall into each category, applicable only to nominal data, e.g. categories (Greene and D'Oliveira 1982).

Subjective Feedback	% Positive feedback (Agree)	Statistical Significant
I prefer the personalized site map than the table of contents	50%	Chi-Square = 5.167, p=0.075 (insignificant)
Personalized site map is useful in navigation	94%	Chi-square = 60.5, p=0 ***
Reading gauge is helpful in personalized site map	84%	Chi-square = 40.5, p=0***

*** Statistically significant at the 1% level

TABLE 7.8: Statistical summary of the subjective feedback for the personalised site map in JointZone

Comments: In the case of users' preference between the personalised site map and the table of contents, 50% of the users preferred the former and 31% had no preference. This might be due to a browsing style where users were still not prepared to give up the conventional table of contents as a navigational aid but at the same time welcomed the idea of a personalized site map.

7.5.5 Task 4: To study the accuracy of the system decision-making in assigning the difficulty level of case study

Group 1	Group 2
Complete an online case study of the difficulty level recommended by the system. (system assigned group)	Complete an online case study of their own choice. (self assigned group)

TABLE 7.9: Task 4 - The allocation of users in the study of adaptive assignment of case studies

Purpose: The purpose of Task 4 was to study the accuracy of the assignment of case studies by the system. This was done by comparing the scores achieved in the case study by groups 1 and 2. Task allocation for both groups is shown in Table 7.9. In order to find out whether the assignment of case studies was accurate, a metric we called 'allocation fitness' was calculated by using the scores of the case studies. For example, if a user scored between 0 to 30% in a case study, the allocation fitness was set to 'too difficult' to indicate the level of case study assigned was higher than the user's knowledge level. If the scores fell between 30 and 80%, they were considered 'optimal' indicating the right level of case study and a score of above 80% gave an allocation fitness of 'too easy'.

Hypothesis 10: -

H_1 = The categorisation of the allocation fitness to the case study in the *system assigned* group is statistically significant.

H_o = The categorisation of the allocation fitness to the case study in the *system assigned* group is statistically *in*significant.

Hypothesis 11: -

H_1 = The categorisation of the allocation fitness to the case study in the *self assigned* group is statistically significant.

H_o = The categorisation of the allocation fitness to the case study in the *self assigned* group is statistically *in*significant.

Group	Allocation fitness			Statistical analysis (chi-square test)
	Too easy	Optimal	Too difficult	
Group 1 (system assigned)	0	6	15	chi-square = 3.86, p = 0.05**
Group 2 (self assigned)	0	9	6	chi-square = 0.6, p = 0.439

** Statistically significant at the 5% level

TABLE 7.10: Statistical analysis on the categorisation of allocation fitness for case study in the system assigned and self assigned group

Results for Task 4: Based on the chi-square test as shown in Table 7.10, the null hypothesis for Hypothesis 10 was rejected. This demonstrates that the categorisation of the allocation fitness in the system assigned group is statistically significant, therefore indicating that the case studies were too difficult for the students in the system assigned group. However in the self-assigned group, the chi-square test proved insignificant leading to the acceptance of the null hypothesis for Hypothesis 11. This indicates that the categorisation of the allocation fitness in the self-assigned group is statistically insignificant.

Comments: As shown in Figure 7.3 for the system assigned group, there were only 6 students who were correctly assigned the right level of case studies. The remaining 15 students found the case study too difficult. However for the self assigned group, a majority of 9 students were in the 'optimal' category and only 6 students fell into the 'too difficult' category. Nevertheless, we cannot claim that the users in the self assigned group have made a better selection than the system in terms of the right level of case studies for them since the results for this are not statistically significant.

A study was done to look at the level of case studies attempted by both groups. The study suggested that in the self assigned group, a majority of the users selected the beginner level in the case studies (see Figure 7.4(a)). This could be due to the factor of 'strategic selection' where users picked the easiest case study on their first attempt, in order to see how they could cope with the basic case studies before they move on to the more difficult ones. In the system assigned group (Figure 7.4(b)), a majority of the users were assigned to the intermediate level

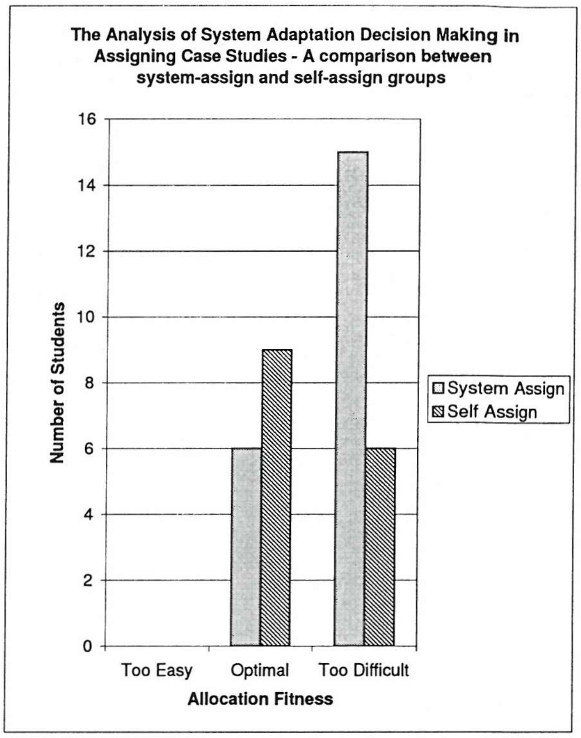
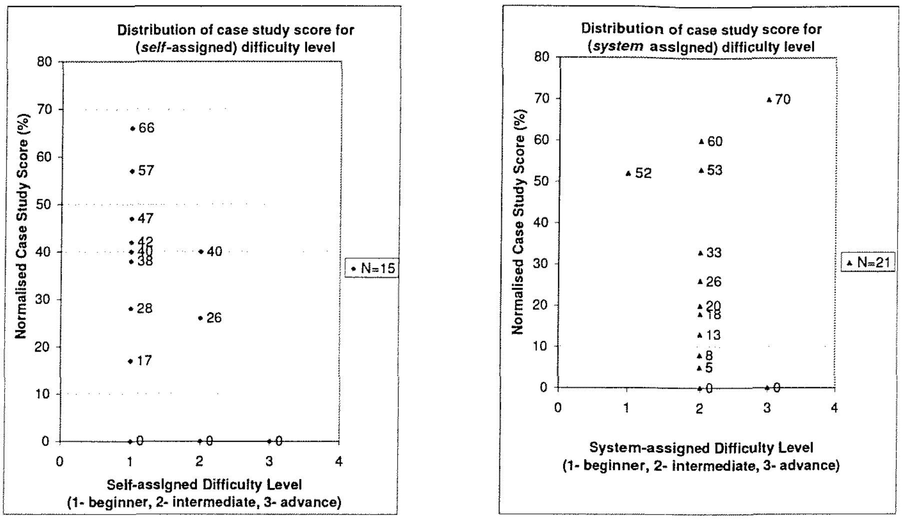


FIGURE 7.3: The comparison of allocation fitness (indication of the accuracy in the assignment of case study) between the system assigned and the self assigned group

and most of them performed poorly in the case studies (below 40%) where they found them too difficult. This suggests that the users might have been assigned to the wrong user group based on the prior knowledge test. This points to the insensitivity of the prior knowledge test and consequently leads to the inaccuracy of the case study assignment.

7.5.6 Task 5: To study the effectiveness of adaptive knowledge-based link hiding when applied to the adaptive reading room

Purpose: This task was designed to test whether the number of links suggested in the adaptive reading room based on the adaptive knowledge-based link hiding feature was appropriate. The result was based on the subjective feedback where a question was used to ask if the subject found the number of links 'just right', 'not enough' or 'too many'. Task allocation for both groups is shown in Table 7.11. Both groups were given the same questionnaire towards the end of the task to study



(a) Self assigned Group (b) System assigned Group

FIGURE 7.4: The distribution of the case study scores according to the user groups (which also corresponses to the difficulty levels of the case studies)

Group 1	Group 2
Used an adaptive reading room to perform further reading on documents relevant to the case study they have just completed in task 4.	Used the non-adaptive reading room for the same purpose.
with adaptive knowledge-based link hiding	*without* adaptive knowledge-based link hiding

TABLE 7.11: Task 5 - The allocation of users for the comparison between the adaptive reading room and the non-adaptive reading room.

their general attitudes towards the reading room, regardless of whether they were using the adaptive or non-adaptive version.

Hypothesis 12: -

H_1 = There is an *appropriate* number of links suggested in *adaptive* reading room.

H_o = There is an *inappropriate* number of links suggested in *adaptive* reading room.

Hypothesis 13: -

H_1 = There is an *appropriate* number of links suggested in *non-adaptive* reading room.

H_o = There is an *inappropriate* number of links suggested in *non-adaptive* reading room.

Hypothesis 14: -

H_1 = The reading room is helpful for finding extra information.

H_o = The reading room is *not* helpful for finding extra information

Hypothesis 15: -

H_1 = Students use the reading room after each case study.

H_o = Students do *not* use the reading room after each case study.

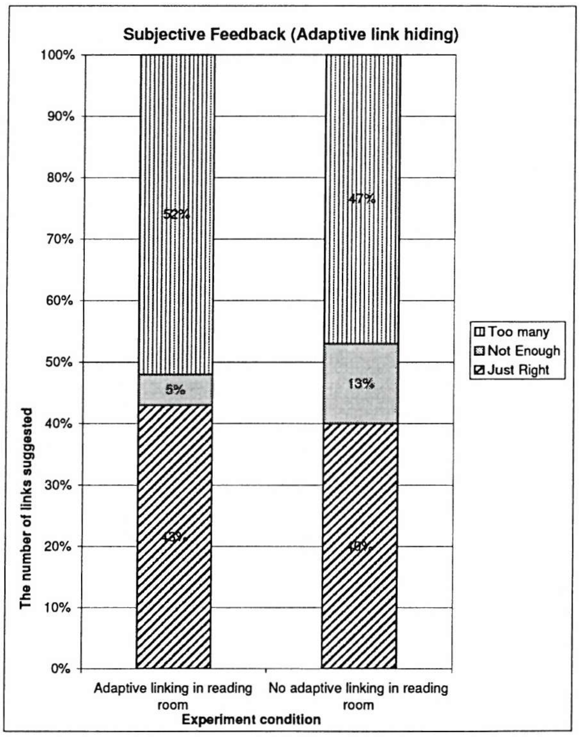


FIGURE 7.5: The subjective feedback on the number of links suggested in the reading room

Results for Task 5: The one-sample chi-square test as shown in Table 7.12 resulted in the acceptance of the null hypothesis for Hypothesis 12. This indicates that there is an inappropriate number of links suggested in the adaptive reading room. However, the test also shows the result are statistically insignificant in the non-adaptive reading room, hence the null hypothesis for Hypothesis 13 was also accepted. This indicates that similarly there is an inappropriate number of links suggested in the

Conditions	Subjective feedback on number of links		Statistical analysis (One-sample chi-square)
	appropriate	inappropriate	
Reading room *with* adaptive link hiding	9	12	Insignificant (p = 0.5)
Reading room *without* adaptive link hiding	6	9	Insignificant (p = 0.4)

TABLE 7.12: Statistical summary of subjective feedback on the number of links in reading room with or without adaptive link hiding.

Subjective Feedback	% Positive feedback (n=36)	Statistical Significant
Reading room is helpful to find extra information	83%	Chi-square = 16, p=0 ***
I will use reading room after each case study	83%	Chi-square = 38, p=0 ***

TABLE 7.13: Statistical analysis of the students' attitude towards the reading room

non-adaptive reading room. In terms of the user's attitude towards the reading room, the chi-square test as shown in Table 7.13 resulted in the rejection of the null hypothesis for Hypotheses 13 and 14 indicating that the students found the reading room helpful for finding extra information and that they would use the reading room after each case study.

Comments: A closer look at the users' subjective feedback for the adaptive reading room as shown in Figure 7.5 reveals that 52% of students felt there were too many links suggested in the reading room with adaptive link hiding. However, in the case of reading room without adaptive link hiding, 47% of students felt that there were too many links and 13% said there were not enough links. This suggests there is a need for adaptive link hiding in a reading room but the current implementation of link hiding is not capable of delivering an appropriate number of links. Nevertheless, a majority number of the students found the reading room, in general (regardless of adaptive or nonadaptive), useful for finding extra information and they indicate they will use the reading room after each case study. The reason for the negative opinion on adaptive link hiding in the reading room could be due to the incorrect adaptation decision-making by the system. For example, a student might be wrongly assigned to a user group that is of a higher level than their knowledge level, with the result that he or she is overwhelmed by the number of links suggested. The evidence of incorrect assignment to a user group can be seen from the poor performance of subjects in the case studies, as shown in the previous task.

7.6 Summary of Results

The above evaluation has shown the rejection of the null hypothesis in each of the cases below, therefore the acceptance of the following hypotheses:-

- Hypothesis 1, H_1 = The *time taken* to complete a task is significantly reduced by the topic map as compared with the table of contents.
- Hypothesis 2, H_1 = The number of *navigational steps* are statistically lower by using the topic map as compared with the table of contents.
- Hypothesis 3, H_1 = The *learning performance* is statistically higher using the topic map as compared with the table of contents.
- Hypothesis 5, H_1 = The number of *navigation steps* is statistically lower by using the personalised topic map (with adaptive history-based link annotation) as compared with the non-personalised topic map (without adaptive history-based link annotation).
- Hypothesis 8, H_1 = The adaptive history-based link annotation (reading gauge) is helpful in the personalised site map.
- Hypothesis 9, H_1 = The personalised site map is useful in navigation.
- Hypothesis 10, H_1 = The categorisation of the allocation fitness to the case study in the *system assigned* group is statistically significant.
- Hypothesis 14, H_1 = The reading room is helpful for finding extra information.
- Hypothesis 15, H_1 = Students will use the reading room after each case study.

The following null hypotheses were accepted which implies the experimental hypothesis is rejected in each case:-

- Hypothesis 4, H_o = The *time taken* to complete a task is *not* significantly reduced by using the personalised topic map as compared with the non-personalised topic map.
- Hypothesis 6, H_o = The *learning performance* is *not* statistically higher for the personalised topic map as compared with the non-personalised topic map
- Hypothesis 7, H_o = There are *no* user's preferences between using the personalized site map and the table of contents.
- Hypothesis 11, H_o = The categorisation of the allocation fitness to the case study in the *self assigned* group is statistically *in*significant.

- Hypothesis 12, H_o = There is an *inappropriate* number of links suggested in the *adaptive* reading room.
- Hypothesis 13, H_o = There is an *inappropriate* number of links suggested in the *non-adaptive* reading room.

7.6.1 Discussion

This evaluation suggests that the topic map significantly reduces the time taken and the number of navigational steps required to complete a task. The learning performance is improved by using the topic map as compared to free browsing using the table of contents. The integration of the history-based adaptive link annotation into a personalised topic map reduces significantly the number of navigational steps required but it makes no significant difference in terms of learning performance and time taken to complete a task. The use of the history-based adaptive link annotation in the personalised site map is significantly helpful to the students based on their subjective opinions. They accepted the personalised site map as useful in navigation. A statistically significant number of students said they would use the reading room after each case study and the statistical analysis indicated that they found the reading room helpful in finding extra information.

One of the possibilities for the incorrect assignment of case study by the system (see Task 4 in Section 7.5.5) and the inappropriate number of links suggested by the adaptive link hiding mechanism in the reading room (see Task 5 in Section 7.5.6) could be due to the insensitivity of the user modeling that lead to the inaccuracy of user group assignment. As shown in Figure 7.4 for the system assigned group, most students were assigned to the intermediate level of case studies and their scores reflected that the case studies were too difficult for them.

We adopted a simple modification by changing the current prior knowledge test set to a set of questions that was more closely related to the case studies and the contents of the site, as shown in Appendix C, Figure C.6. Each question has an option of 'i don't know' to reduce the possibility of answer guessing. There are altogether 23 correct options in the 10 questions. A threshold (see Table 7.14) was set by the domain expert, Rheumatology Consultant Dr. Ray Armstrong, to decide the number of correct answers required in correspondence with each user group. These new sets of questions were tested through email on the same group of subjects who undertook the evaluation (regardless of whether they were in group 1 or 2). We received 15 feedbacks from students who completed this revised prior knowledge test. Based on their scores, 10 of these students were assigned to the beginner level, 4 to the intermediate and 1 to the advanced level. The new prior knowledge test reflected a closer correlation between the students' performance in the prior knowledge test and their competence in the case studies. The chi-square test as shown in Table 7.15 showed that most of them were assigned to the beginners' group instead of the intermediate or advanced level.

Number of correct answers (out of 23)	Assignment of user group
0-10	beginner
11-17	intermediate
18-23	advance

TABLE 7.14: Threshold set in the revised prior knowledge test for the assignment of the difficulty level of case studies / user group

User group assignment			Statistical analysis
Beginner	Intermediate	Advanced	(one sample chi-square test)
10	4	1	Chi-square = 8.4, p=0.015 **

** Statistically significant at 5% level

TABLE 7.15: Allocation of students based on the revised prior knowledge test

7.7 Comparison with Previous Work

As compared to previous work mentioned in Section 5.5, JointZone appears to contribute in a few perspectives.

Firstly, the use of reading speed to implement the history-based link annotation is a novel idea and has not been approached by any of the existing systems. MANIC (see Section 6.4.2.1) has attempted to gauge reading value based on the page length without considering the individual differences in terms of their reading speed, but this method is less accurate as shown by the validation test in section Section 6.4.2.3. Interbook has attempted to implement its page read value through the display of a page but it is obviously not reliable. The approach by JointZone has fulfilled the future work in Hylite+ (see Section 5.5.6) system which pointed out the need to control for the variable of user's reading style. The educational AH community has always concentrated on building adaptive sequences of tasks and concepts that aimed towards individual students' knowledge, as demonstrated by AHA, ELM-ART and INTERBOOK. JointZone has contributed to these existing adaptive approaches by taking into consideration the individual differences in terms of their reading style: fast or slow reader, to implement a more accurate modeling of a user's browsing history.

Secondly, in terms of evaluation, JointZone has demonstrated that history-based link annotation has reduced the number of navigation steps but has no significant effect on student learning, as shown in Section 7.5.3. This agreed with the evaluation outcome of ISIS-TUTOR (see Section 5.5.4) which showed that their implementation of knowledge-based link annotation does not improve learning but reduce the number of visited nodes.

Thirdly, the application of various adaptive features in JointZone has received positive feedback from the users based on their significant positive attitudes towards the usefulness of personalised site map for navigation and a significant number of them will use the adaptive reading room after each attempt of case study. This serves as a useful guideline in terms of judging the user acceptance towards the application of adaptive features. This is in contrast to some of the existing AH systems, i.e. Interbook and ELM-ART which have shown insignificant results in their evaluation outcomes due to users abandoning the usage of adaptive features and opting for non-adaptive features.

7.8 Conclusion

This evaluation has given us an insight into the integration of learning technology into a web-based educational environment. A navigation tool such as the topic map seems to make a significant impact in the facilitation of learning process (i.e. time spent, the number of navigational steps) and the improvement of learning (i.e. learning performance). However, interestingly, it was found that the adaptive techiques such as the adaptive link annotation that was integrated into the personalised topic map does not lead to an improvement in learning performance but facilitates the learning process in terms of reducing the number of steps required to complete a task. In terms of subjective feedback, there was high user acceptance levels towards the various personalised features. Users found the history-based adaptive link annotation useful for the purpose of navigation in the personalised site map. They also found the adaptive reading room helpful for finding extra information and they supported the idea of using the reading room after each case study. This layered evaluation approach has helped us to target the reason for the unsuccessful implementation of the adaptive link hiding. Troubleshooting resulted in the conclusion that users were wrongly assigned to the appropriate level of user group. A correction was applied through improving the sensitivity of the user modeling that is based on a prior knowledge test. A new prior knowledge test set that was more closely related to the case studies and the content of the site was used to replace the old set of prior knowledge inference questions. This new test was tested and demonstrated to be able to model more closely the user's knowledge level in relation to their competence in the case study.

7.9 Summary

This chapter described the evaluation that has been undertaken to study the adaptive features integrated into JointZone. The goal of the evaluation was to find out whether the adaptive features facilitate and improve learning in the web-based environment. The layered evaluation approach was used to achieve a two-fold assessment: firstly to assess how accurate the system is in making assumptions about the users and secondly, how meaningful the adaptive features are to the users. The results were analysed according to subjective (users' opinions) and objective feedback (i.e. time spent, learning performance etc). The outcome of this evaluation shows a high level of acceptance from the users towards various adaptive features. The history-based adaptive link annotation in particular was demonstrated to have reduced the number of navigational steps required as part of the learning process.

Chapter 8

Conclusions and Future Work

8.1 Summary and Conclusions

This thesis presented the development and the evaluation of an adaptive web-based application. The main objective of the work was to integrate adaptivity or personalization into a fully-functional web-based application through the employment of adaptive hypermedia techniques. The implementation of this application was influenced by the motivations to keep the user modeling as simple as possible and also to minimise the involvement of the domain expert. The overall aim of the thesis was to build upon existing methodologies on user modeling and domain modeling for educational adaptive hypermedia.

8.1.1 Pedagogical Goals

This work has achieved its educational attainment in the learning of Rheumatology for medical undergraduates as illustrated in Chapter 4. The application offers not only a library of information that promotes declarative knowledge-based learning but also case studies that facilitate the discovery of procedural knowledge. The case studies have a built-in instant feedback mechanism and an adaptive assignment feature to meet the learning needs of the students. The integration of adaptive hypermedia into the informal learning environment provides assistance to the users without replacing their control in the nature of user-driven exploratory learning.

8.1.2 Linkbase Approach

The linking mechanisms in this work have demonstrated a linkbase approach to link generation within the corpus of information. The use of linkbases enables links to be generated automatically and stored separately from the documents. Local documents that share the same context with an external site's documents were linked effortlessly through associative linking. Glossary terms that spread across the domain were linked to their definitions automatically without the painful process of hand-knitting them into the documents one by one.

8.1.3 Simplicity and Novelty in Implementation

This work has shown that simplicity in the approach of user modeling in capturing user's information. The user model in JointZone captures the users' browsing history and their knowledge level for the provision of history-based link annotation and knowledge-based link hiding. The browsing history was modeled based on the users' reading speed and the page length in order to provide each user with a real time estimation of optimal reading time for each page in the domain. This novel method has provided a better solution than conventional methods that are mostly based on page display or static optimal reading time. One of the advantages of this method is that it can accommodate users' varying reading speed and prior knowledge. A validation test has shown that this method provides a better approximation of the student's understanding in the domain (see section 6.4.2.3). Additionally, the capturing of the users' knowledge level is an explicit process that uses a questionnaire to gain input from the users. The knowledge attribute that was developed based on the user input can update itself automatically and transparently for each user over several uses of the application, reducing the need to intrude on the users.

The work also demonstrated a domain modeling approach that used keyword indexing in domain representation. This approach relieved the domain expert from the time consuming task of organizing the content for adaptation purposes, hence allowing them to concentrate more on the production of the content itself.

Although the user modeling and domain modeling methods mentioned in this work were tested and applied on one specific application, the methodologies are essentially generic and can be applied to other domains with minor modifications. This is especially true with the modeling of the user's browsing history.

8.1.4 Usability Study and Evaluation

A usability study was undertaken to ensure the ease and user-friendliness of the user interface. This study also ensured that the application was not hampered by any flaws in the design of the user interface before any adaptive features were integrated into the system and their effectiveness evaluated.

The evaluation of JointZone was based on a two-fold approach: firstly to assess the accuracy of the system's assumption-making and secondly, to evaluate how meaningful the adaptive features are to the users. The evaluation result revealed a high level of acceptance from the users towards various adaptive features. The users were found to welcome the presence of the adaptive features and they showed interest in using them for various tasks during the evaluation. The history-based link annotation in the personalised topic map was found to have significantly reduced the number of navigation steps required in the learning process.

8.1.5 Conclusion

In a conclusion, this work has achieved its goal in integrating adaptive features into a static web-based medical application. It has successfully provided a personalized learning environment with the implementation of adaptive history-based link annotation and knowledge-based link hiding. JointZone has demonstrated new methodologies in user modeling and domain modeling in making adaptive hypermedia possible without relying on the heavy involvement from the domain expert. The adaptive features were tested on the medical students and received positive subjective feedback. The implementation of history-based link annotation in particular was demonstrated to facilitate the process of learning by reducing the number of navigational steps required. The adaptive approach ultimately adds value to the otherwise one-size-fits-all educational web application, but as currently implemented it has a number of limitations which are discussed in the following section.

8.2 Future Work

8.2.1 User Modeling Enhancement

The user model could be further refined to infer a better representation of the users. In this case, the test used to capture the prior knowledge of the users could be further improved in terms of its accuracy. A confidence log (LTDI 1998) could be used where the users are not only asked to give the correct answers for the questions but also their confidence level in their answers (e.g. very confident, some confidence, little confidence or no confidence). Through this, the system can infer whether a user really possesses the expected knowledge and identify if there is any guess work involved.

In modeling the user's browsing history through the reading effort index, the current considerations of page length and effective reading speed can be extended to include images and videos. This would provide a more accurate and finer grain of estimation as the amount of time required to look at an image or a piece of video could be a significant factor in calculating the optimal reading time for a page (refer to Equation 6.2). The modeling methods could also be expanded to consider browsing activities such as screen scrolling as one of the criteria to ensure that a page is indeed read by the users.

8.2.2 Link Generation Improvement

The current implementation of links and linkbases in JointZone was based on a non-standard definition of linking elements. One suggestion for future work in this area is to alter the current implementation of links to comply with XLink specifications (DeRose, Maler, and Orchard 2001). XLink has the advantage of delivering standardized link metadata to promote better data sharing in the future web. XLink, if fully supported by commercial browsers, has the capability of implementing links on the web in a dynamic way based on a globally conformed standard, thus making the links sharable among different applications.

8.2.3 Intelligent Case Studies

We strongly feel that user interest can be increased significantly if a higher level of complexity and challenges are injected into the system. As shown by the example of this work, the implementation of the procedural knowledge (case studies, see section 4.3) can be made more challenging if the patients' conditions become dynamic. Fuzzy logic[1] (Bezdek 1993) could be used to simulate a patient's condition that is non-static and has the capability to evolve and adapt over time, based on the user's input such as prescription and disease management. The level of complexity could be adapted to the user's knowledge level by providing a more complicated patient's clinical development for an expert and a less complicated one for a beginner.

8.2.4 Long Term Evaluation

An important aspect of the future work is to conduct a longer term evaluation in order to monitor the use of the personalised features by the students over a longer period of time (e.g. an academic semester). This would alleviate the cold start problem where the user model has not been sufficiently built up, due to a short term evaluation, to create more effect on the personalised features.

The longer term evaluation could include a study of the user's progress from one user group to another, as more case studies are completed to fulfill the requirement for a student to be promoted to the next level in the user group hierarchy. This would provide an observation on the students' competence in the current design of case studies. This would be good feedback for the domain expert to help them decide whether the current design needs adjustment or modification (e.g. in the case where the case study is too difficult).

[1]Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth – truth values between "completely true" and "completely false".

A long term evaluation could also study the effectiveness of history-based link annotation in helping students' with their revision on the learning materials, by providing feedback on what they have or have not looked at. This cannot be achieved in a short term evaluation since it is impossible for the students to read most of the documents within a short period of time.

8.2.5 Future Research Direction

This section discusses the likely future direction for this work on a broader perspective.

8.2.5.1 User Study

An important direction for future work lies in the dimension of the user study. It is important to observe and prioritize user needs in a learning environment before providing any adaptive features. The user needs depend on the nature of the tasks involved which in turn are influenced by the type of domain and application. Hence the provision of an adaptive feature that is highly effective in one domain or application might achieve the same result in another domain. Most of the time, the researchers in this area tend to concentrate more on delivering a system rather than meeting the real needs of the user. We suggest the inclusion of a psychological experiment to study the usage and behaviour of users in a static application prior to any integration of adaptive and intelligence features. This will ensure the delivery of a more successful adaptive system that is not only functioning well but also catering well to the users needs.

8.2.5.2 Semantic Web

The current Web has limited capability in integrating information from multiple sites. The existing barrier is the unavailability of a uniform representation of knowledge for the sharing of information between multiple applications and domains. There is a need for the implementation of such a knowledge base in a distributed manner for information reuse. A Web-based application like JointZone is full of knowledge resources that are highly reusable but currently not sharable with other applications. On a different note, there is a need for a more flexible representation of knowledge where the form of representation for a piece of information should not be restricted to only particular keywords.

The current Web offers a seamless way of linking between contents but it is still surprisingly difficult to transfer content between Web applications. However this problem may be alleviated with the arrival of the Web ontology and Semantic Web (Hendler, Berner-Lee, and Miller 2002). An ontology defines the terms used to describe and represent an area of knowledge such as medicine, financial management, archeology, arts, share market, etc (Heflin 2003; Gruber 1993). Ontologies include computer-usable definitions of basic concepts in the domain and the relationships among them. They are made sharable among people, databases, and applications and this makes the knowledge reusable.

The Semantic Web has many advantages over the current Web. It uses new Web languages based on RDF (the Resources Description Framework) that are able to deliver machine-readable 'ontology' to enable knowledge sharing and reuse. This is a step beyond the representation capability of HTML and even the author-defined tagging capability of XML. The new form of representation is able to expand the definition or representation of current domain modeling in JointZone or any other AH applications. Instead of using keywords or concepts, the Web Ontology Language (OWL) (Heflin 2003) is able to deliver a more descriptive representation of knowledge.

```
Oncogene(MYC)
    Found_in_Organism(Human)
    Gene_Has_Function(Transcriptional_Regulation)
    Gene_Has_Function(Gene_Transcription)
    In_Chromosomal_Location(8q24)
    Gene_Associated_With_Disease(Brukitts_Lymphoma)
```

TABLE 8.1: An expanded definition for an oncogene, as part of the Metathesaurus project by the Center for Bioinformatics of the US, National Cancer Institute (NCI), excerpt from (Hendler 2003)

Table 8.1 shows an example of expanded definition of a domain in bioinformatics. Instead of just representing the oncogene, MYC, with a few keywords, e.g. 'Human', 'Transcriptional Regulation', 'Gene Transcription, '8q24', 'Brukitts Lymphoma', the OWL-based representation is expanded to specifically define that MYC is found in humans, it has the functions of gene transcription and transcriptional regulation, its unique location is 8q24, and it is associated with Brukitts Lymphoma disease. The oncogene definition above has provided an example of a representation of domain that is not restricted to particular keywords. It has also demonstrated that this type of knowledge representation, by virtue of being made machine-readable, can be shared among different Web sites and applications.

This type of expanded domain representation caters appropriately for the domain of JointZone, for it allows the rich resources of the content to be made sharable with other applications, particularly those in the medical domain. From the perspective of web-based adaptive hypermedia, we can rely on the semantic web to further alleviate the involvement of the domain expert in the domain modeling since ontologies take the role of defining content in the semantic web. This suggests that the domain modeling of JointZone could readily adopt these well defined ontologies that promise more meaningful representation as compared to the keyword representation of the domain.

8.2.5.3 Web Services

Most of the AH systems now appear as Web applications that are merely serving information. Web services are a new breed of Web applications that are able to perform functions or services over a wealth of information and resources on the Internet rather than just displaying them. A web service has the capability of combining content from different resources and perform functions on these resources (Tidwell 2000; Ananthamurthy 2003). It fits in the trends where content is becoming more dynamic based on the XML technology, and pervasive computing is gaining popularity as information is retrieved not only through traditional browsers but all sorts of wearable devices and platforms. The Web is heading towards cheaper bandwidth and storage that allows services to be delivered instead of mere information.

Adaptive hypermedia is an area that is well suited to the web services approach. The AH community has been concentrating on delivering contents and links according to a user's profile, which essentially are adaptive 'services'. For example, providing a personalised TV program list, presenting an adaptive museum tour, adapting an educational course to students and personalising the handling of request for a document, etc. We envisage future AH systems that are implemented within the Web services context. Unlike conventional AH systems, adaptive web services are built upon a wealth of XML-RDF data which enable them to provide adaptive services to different web applications and serves different platforms. The following two examples are given in the domain of medical and commercial:-

- a medical web service that runs on a wealth of medical theory and data, that is able to provide services such as diagnosing a patient's condition, handling a request for a medical thesaurus or a disease profile, running a biology test and providing a simulation of disease management. All these can be made adaptive to the requestor's profile, e.g. patient's condition, medical prior knowledge, devices or platform requirement etc.
- a commercial online purchase store that is implemented in a web services context will be able to deliver services such as cross-comparison of prices, delivery of goods information, presenting instructions, etc. These functions can be adapted to a customer's interest, budget, background and concerns.

The scenario above is made possible by the availability of new standards such as:-

- *WSDL*, which stands for Web Service Definition Language (Christensen, Curbera, Meredith, and Weerawarana 2001). A web service relies on WSDL to define the services that it is offering to the user community.

- *SOAP*, which stands for Simple Object Access Protocol (Don Box, Ehnebuske, Kakivaya, Layman, Mendelsohn, Nielsen, Thatte, and Winer 2000). SOAP provides a more robust and flexible protocol for Web services to interact with a remote machine.
- *UDDI*, which stands for Universal Discovery, Description and Integration (OASIS 2003). All Web services is able to discover each other based on the UDDI specification. UDDI enabled a registry of service to be distributed across the Web. Web services use this registry to register their own services and at the same time search for other services available from third party.

The next generation of AH applications would be implemented in Web services that allow sharing of their adaptive functions, contents and user models with other domain and applications. This is possible since Web services provide standard methods for communication, use a uniform data representation and exchange mechanism, possess a standard meta language to describe the services offered, and have a mechanism to register and locate Web Services-based applications. With all these, it will be a challenge for future AH applications for it is no longer being built as standalone application, rather it is required to be made available as sharable components or services within the community of AH. For example, JointZone could reuse an adaptive medical thesaurus that is adopted from a different AH application to fuel its provision of adaptive glossary links and at the same time make its content available adaptively as a library of resources to other AH applications.

8.2.6 Conclusion

The future AH applications and systems will certainly benefit from the advances of web technologies that promise more efficient organisation of content and better sharing of information. The availability of web services and semantic web will enable the AH research community to build more dynamic AH systems that are made sharable with other applications. This would inevitably make the development of AH system faster and easier, for instead of building a AH application from scratch, different adaptive components from different existing AH applications can be combined to present a new AH system. This will facilitate a new age of information that witnesses the dramatic increase in the publishing of adaptive applications and systems. Personalisation of information will no longer be a luxury but a basic necessity in the future information age.

Appendix A

Case Studies

This appendix shows a number of sample screen shots and implementation details of the case studies:-

- Table A.1: The sample code for constructing 'Score board bean' used in every case study for the interactive mechanism
- Table A.2: The sample code for using bean in Java server pages

TABLE A.1: Score board bean: A Java bean written for keeping track of score and provide instant feedback to the users

```
/**
 * @author created by Muan Hong Ng
 * @version 16/5/01
 * method use in jsp:
*/
package mcqutility;
import javax.servlet.http.*;

public class IntermediateScoreBoardBean{

    private int runningScore;   //user's answer for current screen
    private int maxScore;       //positive answer for current screen
    private int totalScore;     //total score for all screens
    private boolean q1_status;  //user status for screen one
    private boolean q2_status;
    private boolean q3_status;
    private boolean q4_status;
    private boolean q5_status;
    private boolean q6_status;
    private boolean q7_status;
    private boolean q8_status;
    private boolean q9_status;
    private boolean q10_status;

    public IntermediateScoreBoardBean(){ //constructor

        runningScore = 0;
        maxScore = 0;
        totalScore = 0;
        q1_status = false;
        q2_status = false;
        q3_status = false;
        q4_status = false;
        q5_status = false;
        q6_status = false;
        q7_status = false;
        q8_status = false;
        q9_status = false;
        q10_status = false;
    }
    public void addScore(int s){ //use in mark method

        runningScore += s;      //user's score for current screen
        maxScore += s;          //max score for current screen
    }
```

continue next page ...

```
public void minusScore(int s){ //use in mark method

    runningScore += s; //s is negative
}
//check if user got all correct for current screen
public boolean allCorrect(int perfectScore){

    if(perfectScore == maxScore && runningScore == maxScore) return true;
    else return false;
}
public void resetScore(){

    runningScore = 0;
    maxScore = 0;
}
public int getMaxScore(){

    return maxScore;
}
public int getTotalScore(){

    return totalScore += runningScore;
}
public int getRunningScore(){

    return runningScore;
}
public int getPercent(int totalScore, int perfectScore){

    if(totalScore >= 0)
        return ((int)((double)totalScore/(double)perfectScore * 100));

    else return 0;
}
public String getRemark(int percent){

    String remark = "";
    //<25%
    if(percent<=24) {
        remark = "This is a low score which indicates that either
        your knowledge of this area needs improving (consult
        the documents on the site to help you) or you need more
        practice in applying your knowledge (try the case study again).";
    }
```

continue next page ...

```
        //25%-49%
        else if(percent<=49){
            remark = "This score is rather low. You may wish to try
            this case again after further study. These case studies
            allow you to apply your existing knowledge to a clinical
            scenario. Reflect on your score and decide if your knowledge
            of the subject area needs refreshing.  If so, then read around
            the topics raised by the case study.  Alternatively, if you
            had difficulty in applying your current knowledge to clinical
            decision making, then try this case study again and note
            where you are having difficulties.";}
        //50%-74%
        else if(percent<=74){
            remark = "You performed quite well in this case study.
            You may wish to try the case again to see if you can improve
            your score and hence your clinical decision-making skills.";}
        //75% above
        else{
            remark = "Your performance in this case study was very good.
            You seem to be able to apply your knowledge to clinical cases
            effectively.
            To further practice your clinical decision making skills, try any
            other cases that you have not yet
            attempted.";}
        return remark;
    }
    public String getShortRemark(int percent){

        String remark = "";

        //<25%
        if(percent<=24) remark = "You need to understand the subject
         better or improve your clinical decision making skills. Try again.";
        //25%-49%
        else if(percent<=49) remark = "Improve your score by increasing
         your knowledge of this area and reflecting on your clinical
         decision making skills. Try again.";
        //50%-74%
        else if(percent<=74) remark = "Your score indicates you are applying
         your knowledge to a clinical setting. Reflect on any difficulty with
         this case study and try to improve it, if necessary following further readin
        //75% above
        else remark = "You have applied your knowledge to the clinical
         case study well. Try the next one.";

        return remark;
    }
```

continue next page ...

```
    //mark each question for current screen
    //status 1 or -1 for correct or incorrect multiple choice q
    public String mark(HttpServletRequest request, String qno , int status){

        String result = null;
        String scoreS = null;
        int point = 0;

        try{ //if checked, get answer = 1 or -1,
            scoreS = request.getParameter(qno);
            point = Integer.parseInt(scoreS);

            if(point > 0){
                result = "correct"; //correct answer, display tick
                addScore(point);
            }else if(point < 0){
                result = "wrong";// wrong, display cross
                minusScore(point);
            }
        }catch(Exception e){ //if not checked

            if(status > 0){ //correct answer but not selected
                result = "circle"; //display circle
            }else if(status < 0){ //wrong answer but not selected
                result = "neutral"; //display nothing
            }
        }
        return result;  //return image filename for gui
    }
    public void setStatus(int no){//prevent repeat n cheating

        switch(no){
            case 1:
                q1_status = true;
                break;
            case 2:
                q2_status = true;
                break;
            case 3:
                q3_status = true;
                break;
            case 4:
                q4_status = true;
                break;
            case 5:
                q5_status = true;
                break;
```

continue next page ...

```
            case 6:
                q6_status = true;
                break;
            case 7:
                q7_status = true;
                break;
            case 8:
                q8_status = true;
                break;
            case 9:
                q9_status = true;
                break;
            case 10:
                q10_status = true;
                break;
            default:
                System.err.println("error in bean: mcqutiity.IntermediateScoreBoardBe.
                setStatus()");
                break;
        }
    }
     public boolean getStatus(int no){

        boolean s = false;
        switch(no){
            case 1:
                s = q1_status ;
                break;
            case 2:
                s = q2_status;
                break;
            case 3:
                s = q3_status;
                break;
            case 4:
                s = q4_status;
                break;
            case 5:
                s = q5_status;
                break;
            case 6:
                s = q6_status;
                break;
            case 7:
                s = q7_status;
                break;
            case 8:
                s = q8_status;
                break;
```

continue next page ...

```
            case 9:
                s = q9_status;
                break;
            case 10:
                s = q10_status;
                break;
            default:
                System.err.println
                ("error in bean: mcqutiity.
                IntermediateScoreBoardBean.getStatus()");
                break;
            }
        return s;
    }

    public void resetStatus(){  //reset for new case
        q1_status = false;
        q2_status = false;
        q3_status = false;
        q4_status = false;
        q5_status = false;
        q6_status = false;
        q7_status = false;
        q8_status = false;
        q9_status = false;
        q10_status = false;
        totalScore = 0;
        resetScore();
    }
}
```

... end of code

Table A.2: The use of the 'score board bean' in the java server pages for a case study (intermediate)

```
<% //The bean is declared and given an id as 'scorekeeper' %>
<jsp:useBean id = "scorekeeper" class = "mcqutility.ScoreBoardBean" scope = "session":
<jsp:setProperty name="scorekeeper" property="*"/>
</jsp:useBean>
<%  //jsp code
    String submitYes = "no";
    String temp = null;
    boolean yes = false;

    try{

        submitYes = request.getParameter("sb");
        if(submitYes.equals("GO!")) yes = true;

    }catch(Exception e){

        yes = false;
    }

%>
<% HTML bit: feedback part%>
<%
    if(yes){

%>
    <SPAN class="casetitle">Question 1 (out of 8):</SPAN>    <BR/>
      Which one of the following symptoms would you most expect the patient to report
      if this was classic carpal tunnel syndrome?

      <IMG BORDER="0" ALIGN = "middle"
      SRC= "../images/<%=scorekeeper.mark(request, "q1", 1)%>.gif"/>
      Paraesthesiae affecting the whole hand.<BR/><BR/>

      <IMG BORDER="0" ALIGN = "middle"
      SRC= "../images/<%=scorekeeper.mark(request, "q2", -1)%>.gif"/>
      Paraesthesiae affecting the thumb, index and middle
      fingers and half of the ring finger.<BR/><BR/>

      <IMG BORDER="0" ALIGN = "middle"
      SRC= "../images/<%=scorekeeper.mark(request, "q3", -1)%>.gif"/>
      Paraesthesiae affecting the whole arm.<BR/><BR/>

      <IMG BORDER="0" ALIGN = "middle"
      SRC= "../images/<%=scorekeeper.mark(request, "q4", -1)%>.gif"/>
      Numbness affecting the thumb.<BR/><BR/>
```

continue next page ...

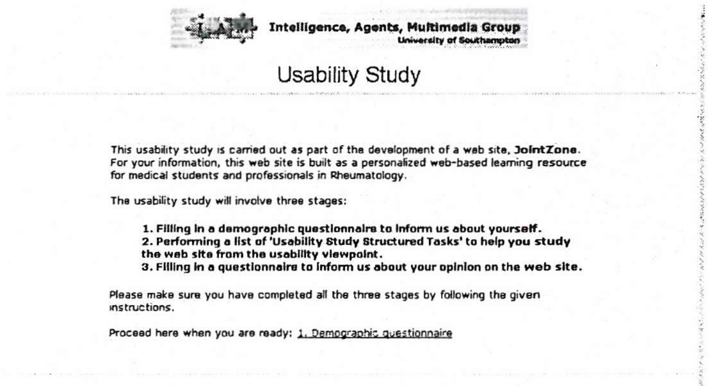
```
<%if(!scorekeeper.getStatus(1)){%>

      Your score for this screen = <%= scorekeeper.getRunningScore()%> / 1
      Your total score so far is <B><%= scorekeeper.getTotalScore()%>.
<%
      if(scorekeeper.allCorrect(1)){
%>
       well done, you have got all the answers on this screen right!
<%    }
      scorekeeper.setStatus(1);
}else{
%>
            <SPAN class="alert">You have already attempted this before!</SPAN>
<%}%>
            <DIV id = "feedback">
            <B>Feedback:</B> in classic carpal tunnel syndrome ...
            ... predominantly the lateral three digits that are affected.
            </DIV>
<%
    }else{

    scorekeeper.resetScore();
%>
<% main HTML bit: question part%>
<HTML>
<HEAD>
<TITLE>Case 1 - Intermediate: Question 1</TITLE>
    <LINK REL="STYLESHEET" TYPE="text/css" HREF="../xsl/case.css"></LINK>
    <LINK REL="STYLESHEET" TYPE="text/css" HREF="../xsl/nav.css"></LINK>
    <SCRIPT language = "JavaScript" SRC="../xsl/interactive.js"></SCRIPT>
</HEAD>
<BODY>
     <FORM method = "post" action = "question1c1.jsp">
     <SPAN class = "small">Which one of the following symptoms would
     you most expect the patient to report if this was classic
     carpal tunnel syndrome?
     </SPAN><BR/><DIV>
     <INPUT NAME = "q1" TYPE = "checkbox" value = "1"/>
            Paraesthesiae affecting the whole hand.
     <INPUT NAME = "q2" TYPE = "checkbox" value = "-1"/>
            Paraesthesiae affecting the thumb,
            index and middle fingers and half of the ring finger
     <INPUT NAME = "q3" TYPE = "checkbox" value = "-1"/>
            Paraesthesiae affecting the whole arm.
     <INPUT NAME = "q4" TYPE = "checkbox" value = "-1"/>
            Numbness affecting the thumb.
     </DIV><SPAN class = "small">Click here to see the feedback: </SPAN>
     <INPUT TYPE = "submit" NAME = "sb" VALUE = "GO!"/>
     </FORM>
</BODY>
</HTML>
```

... end of code

Appendix B

Usability Study

This appendix shows the online demographic questionnaire, usability task and post-questionnaires used in the usability study (Heuristic evalutation approach). Also attached the detailed calculation of the usability criteria on Likert Scale.



Intelligence, Agents, Multimedia Group
University of Southampton

Usability Study

This usability study is carried out as part of the development of a web site, **JointZone**. For your information, this web site is built as a personalized web-based learning resource for medical students and professionals in Rheumatology.

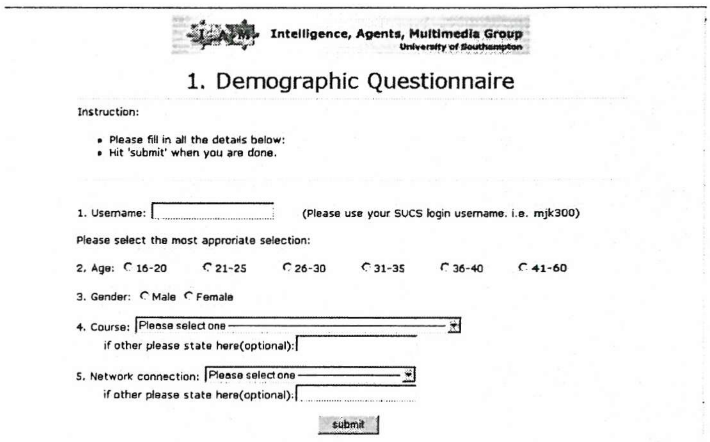
The usability study will involve three stages:

1. Filling in a demographic questionnaire to inform us about yourself.
2. Performing a list of 'Usability Study Structured Tasks' to help you study the web site from the usability viewpoint.
3. Filling in a questionnaire to inform us about your opinion on the web site.

Please make sure you have completed all the three stages by following the given instructions.

Proceed here when you are ready: 1. Demographic questionnaire

FIGURE B.1: The introduction page to the online usability study



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University of Southampton

1. Demographic Questionnaire

Instruction:

- Please fill in all the details below:
- Hit 'submit' when you are done.

1. Username: (Please use your SUCS login username. i.e. mjk300)

Please select the most approriate selection:

2. Age: 16-20 21-25 26-30 31-35 36-40 41-60

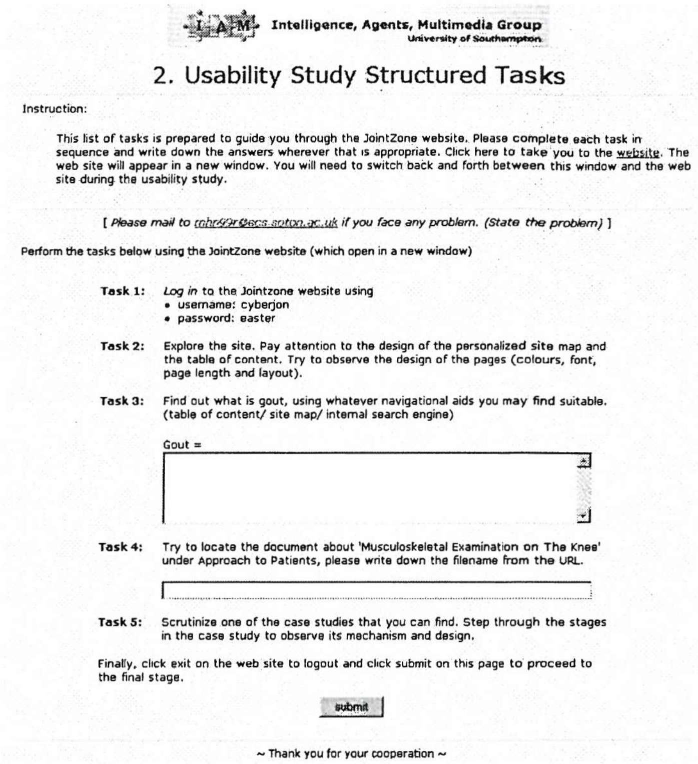
3. Gender: Male Female

4. Course: Please select one
if other please state here(optional):

5. Network connection: Please select one
if other please state here(optional):

submit

FIGURE B.2: The demographic questionnaire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University of Southampton

2. Usability Study Structured Tasks

Instruction:

This list of tasks is prepared to guide you through the JointZone website. Please complete each task in sequence and write down the answers wherever that is appropriate. Click here to take you to the website. The web site will appear in a new window. You will need to switch back and forth between this window and the web site during the usability study.

[*Please mail to mhr99r@ecs.soton.ac.uk if you face any problem. (State the problem)*]

Perform the tasks below using the JointZone website (which open in a new window)

Task 1: *Log in* to the Jointzone website using
- username: cyberjon
- password: easter

Task 2: Explore the site. Pay attention to the design of the personalized site map and the table of content. Try to observe the design of the pages (colours, font, page length and layout).

Task 3: Find out what is gout, using whatever navigational aids you may find suitable. (table of content/ site map/ internal search engine)

Gout =

Task 4: Try to locate the document about 'Musculoskeletal Examination on The Knee' under Approach to Patients, please write down the filename from the URL.

Task 5: Scrutinize one of the case studies that you can find. Step through the stages in the case study to observe its mechanism and design.

Finally, click exit on the web site to logout and click submit on this page to proceed to the final stage.

submit

~ Thank you for your cooperation ~

FIGURE B.3: The tasks to guide users to the usability study

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University of Southampton

3. Post Questionnaire

Instruction: Please select one feedback for each statement:

Navigation	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. The table of content (TOC) helps me a lot in getting around the site.	1	2	3	4	5
2. The depth of the hierarchy of the TOC is ideal.	1	2	3	4	5
3. The site map is useful.	1	2	3	4	5
4. I was always confused about 'where I was'.	1	2	3	4	5
5. I have difficulty locating the information required.	1	2	3	4	5

Access	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6. The registration process is easy and straightforward.	1	2	3	4	5
7. I have difficulty logging into the system.	1	2	3	4	5
8. The download time of the pages is too long.	1	2	3	4	5
9. The system response quickly to my input.	1	2	3	4	5
10. I found the overall access to the site convenient.	1	2	3	4	5

Information Presentation	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11. The layout and structure of the website is clear and meaningful.	1	2	3	4	5
12. I don't like the colours of the site presentation.	1	2	3	4	5
13. The font size of the text displayed is too small or too big.	1	2	3	4	5
14. The length of the page is too long.	1	2	3	4	5
15. There is a consistent display of menu and TOC on every page.	1	2	3	4	5
16. The instructions given in the site are easily understood.	1	2	3	4	5

Subjective Satisfaction	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
17. I enjoy working with the site.	1	2	3	4	5
18. I like the presentation style of the web site.	1	2	3	4	5
19. I get frustrated because I don't have control with the system.	1	2	3	4	5
20. The case studies are clear and helpful.	1	2	3	4	5
21. I felt the web site provide a good opportunity to learn about Rheumatology.	1	2	3	4	5
22. I like the adaptive features on this site.	1	2	3	4	5

23. Further Comment(optional):

submit

FIGURE B.4: The questionnaire at the end of the study

	A	B	C	D	E	F
1	Username	nav1	nav2	nav3	nav4	nav5
2	abdm100	4	2	2	3	4
3	agi100	4	5	3	5	4
4	aj200	4	4	3	4	5
5	arb200	4	4	4	4	4
6	bjma199	4	3	1	3	3
7	bjs100	5	4	3	4	5
8	bk100	4	4	4	4	4
9	bns100	4	4	3	2	3
10	cjm100	4	4	5	4	4
11	dc600	4	4	4	5	5
12	dc899	2	2	3	4	3
13	drb100	4	4	2	3	4
14	gej100	5	5	5	4	5
15	hjm200	2	4	2	4	2
16	iwe100	4	4	3	2	4
17	jcgl100	4	3	5	4	4
18	jdf200	3	3	2	4	4
19	jdw100	4	4	3	4	2
20	ks100	4	4	3	5	5
21	mcr100	4	2	4	4	4
22	mkg100	5	3	3	4	4
23	mt500	2	3	1	1	1
24	mt600	3	3	4	1	4
25	mtl200	4	4	4	3	4
26	njg100	3	3	3	4	3
27	phm100	4	3	1	2	4
28	pl700	4	4	4	3	5
29	san100	4	3	3	5	5
30	sdlp100	4	4	4	4	5
31		110	103	91	103	113

Category	Navigation	Access	Presentation	Subjective Feedback
No questions (Q)	5	5	6	6
Total Score (T)	520	592	589	602
T / (Q + N)	3.5862	4.0827	303850	3.4597

TABLE B.1: The tabular on top shows part of the spreadsheet recording the user's feeback for the 'navigation' category (5 questions). The table below shows the calculation of the usability criteria on Likert Scale for the total subjects, N = 29

Appendix C

User Modeling

This appendix shows the registration form and the set of tests used in user modeling of JointZone.

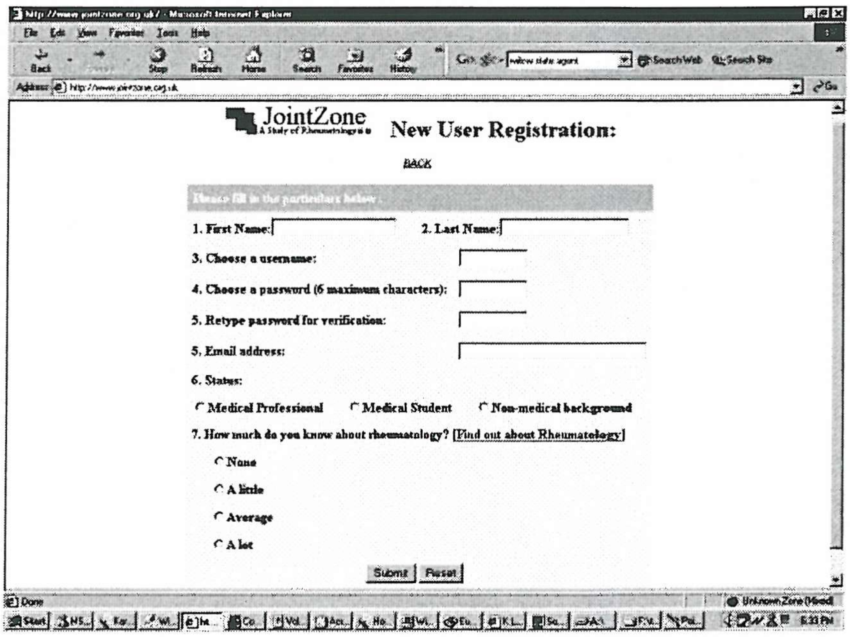


FIGURE C.1: The online registration form for user's registration with the system

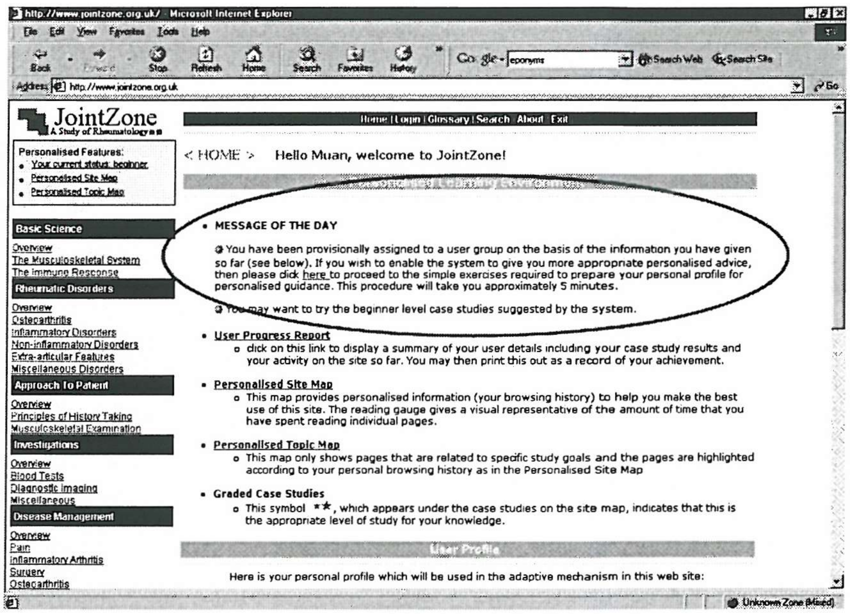


FIGURE C.2: The guideline prompting users to the prior knowledge test and the recording of their reading speed

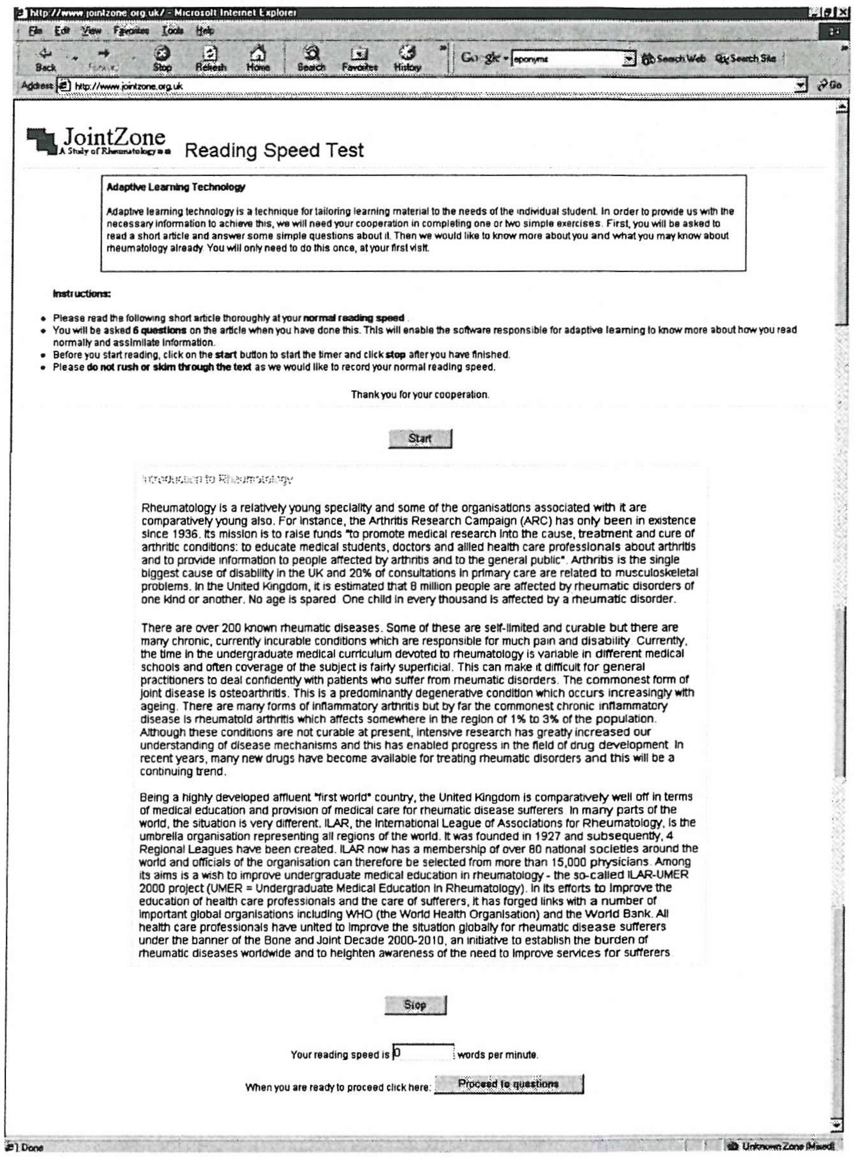


FIGURE C.3: The reading speed test used to capture the user's effective reading speed

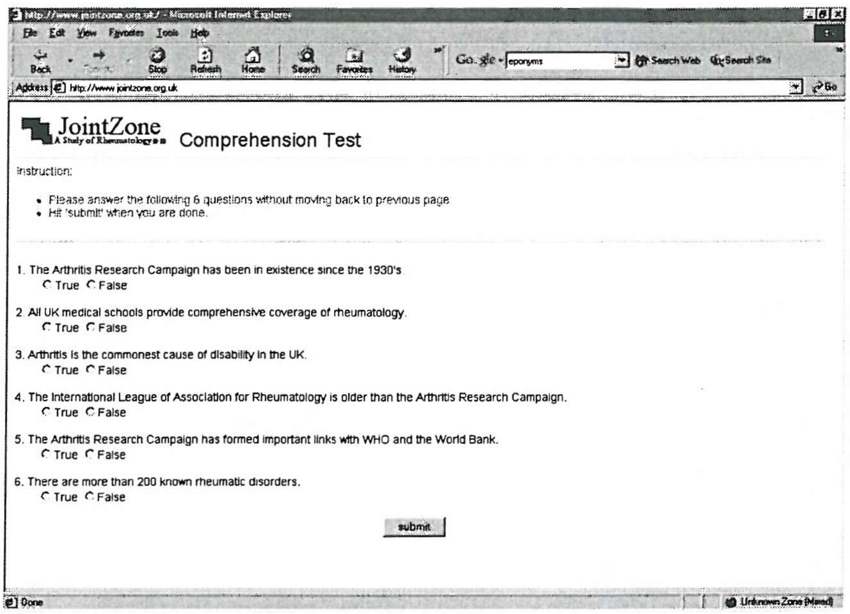


FIGURE C.4: The comprehension test used to capture the user's effective reading speed

JointZone
A Study of Rheumatology

Prior Knowledge Test

Instruction:

- Please answer the following 10 questions
- Hit 'submit' when you are done

1. What is the DMARD (disease modifying antirheumatic drug) of first choice for treating rheumatoid arthritis?
   - Gold
   - Methotrexate
   - Steroid
   - Cyclophosphamide

2. In which part of the body does one find De Quervain's tenosynovitis?
   - Knee
   - Shoulder
   - Wrist
   - Foot

3. Which of the following joint disorders occurs most commonly in the UK?
   - Osteoarthritis
   - Rheumatoid arthritis
   - SLE
   - Gout

4. Raynaud's phenomenon occurs most commonly in which of these conditions?
   - Rheumatoid arthritis
   - Ankylosing spondylitis
   - Scleroderma
   - Systemic lupus erythematosus

5. Which of the following terms correctly describes a knock-knee appearance?
   - Valgus
   - Varus

6. Which of the following conditions may be associated with the possession of the tissue type HLA B27?
   - Gout
   - Ankylosing spondylitis
   - rheumatic fever
   - Rheumatoid arthritis

7. What is the name given to the swellings on the joints at the end of the fingers in some patients with arthritis?
   - Rheumatoid nodules
   - Bouchard's nodes
   - Heberden's nodes
   - Tophi

8. Which condition is associated with the presence of the radiographic phenomenon of bilateral hilar lymphadenopathy?
   - SLE
   - Lyme disease
   - Sarcoidosis
   - Takayasu's disease

9. Which of the following tests would you request first if you suspected a patient of having ankylosing spondylitis?
   - Radiograph of sacroiliac joints
   - ESR
   - HLA DR4
   - HLA B27

10. Which of the following symptoms is the most suggestive of an inflammatory cause for joint symptoms?
    - Prominent nocturnal pain
    - Swelling
    - Pain increasing of the day goes on
    - Prominent morning stiffness

submit

FIGURE C.5: The prior knowledge test used to capture the user's domain knowledge level in Rheumatology

JointZone A Study of Rheumatology

Prior Knowledge Test

Instruction:

- Please answer the following 10 questions
- Hit 'submit' when you are done

(More than one option may be correct for each question)

1. Which of the following clinical features indicate high probability of an inflammatory rather than non-inflammatory cause for rheumatic symptoms?

☐ *I don't know*
☐ Morning stiffness of 90 minutes' duration.
☐ Post-inactivity stiffness ("gelling") which is more pronounced than morning stiffness
☐ A one-week history of joint symptoms.
☐ Little change in symptoms on taking corticosteroid.
☐ An ESR of 19 mm/h

2. Which of the following statements about osteoarthritis are true?

☐ *I don't know*
☐ Osteoarthritis may follow a previous joint injury
☐ Osteoarthritis commonly occurs secondary to inflammatory joint disease
☐ There are no genetic influences in the aetiology of osteoarthritis
☐ Periarticular osteopenia is common in osteoarthritis
☐ The ESR is moderately raised in osteoarthritis.

3. Low back pain with leg pain in a young adult:

☐ *I don't know*
☐ Often results from sleeping in an awkward position
☐ Usually suggests an intervertebral disc lesion with nerve root impingement
☐ Is often preceded by heavy lifting
☐ May be accompanied by paraesthesiae in the foot.
☐ Is seldom associated with disturbance of bladder function

4. Which of the following statements about gout are true?

☐ *I don't know*
☐ This usually affects middle-aged males
☐ Symptoms usually start in late adolescence
☐ It is not unusual for elderly females to be affected
☐ Subcutaneous deposits of urate are known as Osler's nodes.
☐ All hyperuricaemic individuals will inevitably develop gouty arthritis unless the urate is lowered

5. In carpal tunnel syndrome:

☐ *I don't know*
☐ The patient's predominant symptom is weakness of the hand.
☐ The patient typically reports that paraesthesiae most often occur on gripping objects tightly
☐ Pain may sometimes be experienced in the shoulder
☐ The patient is often awoken at night by the symptoms
☐ The condition frequently occurs in hyperthyroidism.

6. Which of the following statements about rheumatoid arthritis (RA) are true?

☐ *I don't know*
☐ The prevalence is approximately 0.1% of the adult population
☐ Rheumatoid nodules are most often to be found near the elbow
☐ About 50% of patients with RA are seropositive for rheumatoid factor
☐ Most patients have symmetric joint involvement.
☐ The treatment of choice if nonsteroidal anti-inflammatory drugs are insufficiently effective is oral corticosteroid.

7. In the case of polymyalgia rheumatica, which statements are true.

☐ *I don't know*
☐ Polymyalgia rheumatica often affects individuals in their 40s.
☐ The ESR is normal in approximately 50% of cases of polymyalgia.
☐ Polymyalgia rheumatica causes limb girdle pain and stiffness which is usually worst in the middle of the day.
☐ A small proportion of patients with polymyalgia develop cranial arteritis
☐ It is usually possible to abolish polymyalgic symptoms with no more than 20 milligrams of prednisolone daily.

8. Which of the following statements about shoulder pain are true?

☐ *I don't know*
☐ Cervical spine problems not infrequently result in pain referred to the shoulder.
☐ Pain and stiffness of the shoulder is a relatively common occurrence in diabetes
☐ Rotator cuff tendonitis may cause restriction of active movement and even more restriction of passive movement.
☐ The treatment of choice for rotator cuff tendonitis is surgery.
☐ Shoulder pain is common in the population at large

9. Which of the following statements about investigations in rheumatology are true?

☐ *I don't know*
☐ An ESR of greater than 20 mm/h always indicates the presence of an inflammatory process.
☐ The rheumatoid factor test is the best way of distinguishing between rheumatoid arthritis and other inflammatory rheumatic disorders.
☐ X-rays are helpful in distinguishing between inflammatory arthritis and osteoarthritis
☐ The appearance of synovial fluid can help distinguish between inflammatory and non-inflammatory joint disorders.
☐ In diagnosing ankylosing spondylitis, testing for HLA B27 is essential

10. Which of the following conditions have been appropriately matched to their physical signs?

☐ *I don't know*
☐ Heberden's nodes and osteoarthritis
☐ Pregnancy and carpal tunnel syndrome
☐ Tophus and pseudogout.
☐ Osteophyte and rheumatoid arthritis
☐ Polymyalgia rheumatica and diplopia.

[submit]

FIGURE C.6: The *revised* prior knowledge test used to capture the user's domain knowledge level in Rheumatology

Appendix D

Validation Test

This appendix shows the tests used in the validation of the reading effort index methodology in JointZone.

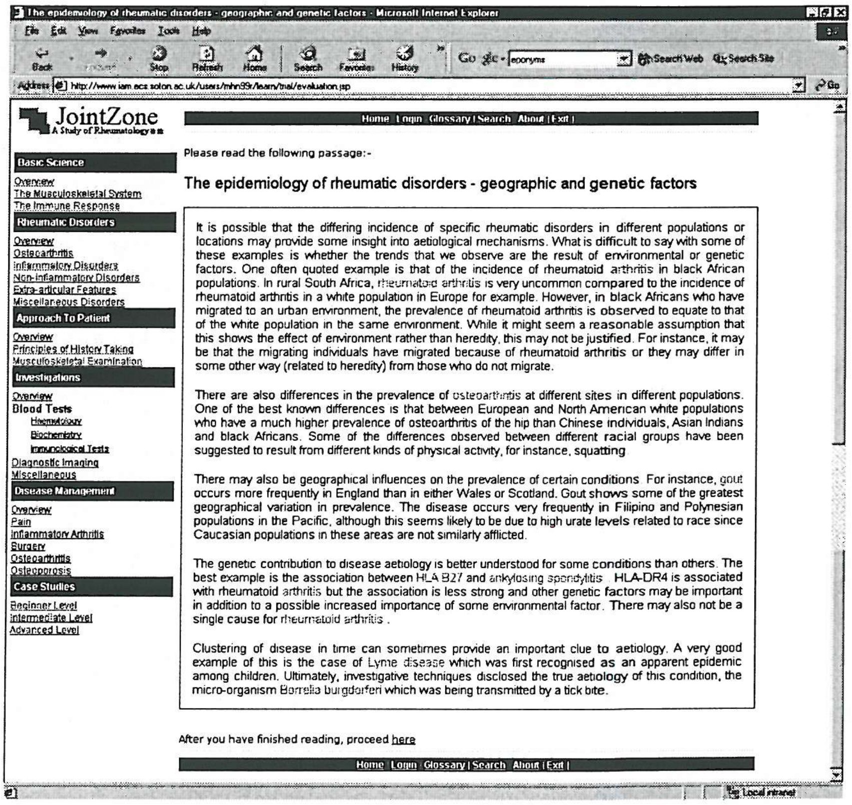


FIGURE D.1: The validation test (reading text) used in validating effort index

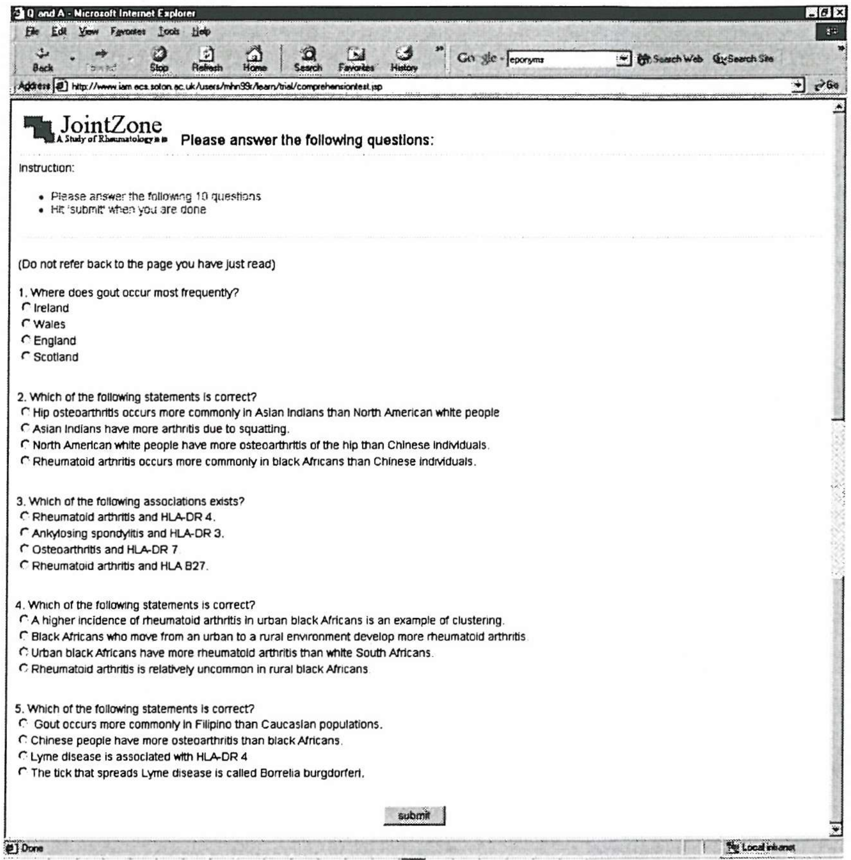


FIGURE D.2: The validation test (measure understanding) used in validating effort index

Appendix E

The Evaluation

This appendix shows the set of tasks, pre- and post-tests used in the evaluation of JointZone.

- A1 - Tasks for group 1 (experimental group).
- A2 - Tasks for group 2 (control group).
- B - Pre-test of task 1 and task 2, for both groups.
- C - Post-test for task 1 (Psoriatic Arthritis), for both groups.
- D - Post-test for task 2 (Rheumatoid Arthritis), for both groups.

Adaptive Hypermedia Research

A1

Fill in your personal details:

Name: ______________________

Year of Study: ____________ Email: ____________________

How often do you surf the Internet or check your email:
Everyday ☐ *once/twice a week* ☐ *once/twice a month* ☐ *rarely/never* ☐

Tasks for Group 1

1. Paper-based prior knowledge test.

   - Attempt the questions given in **paper B** – *(Pre-test for Psoriatic Arthritis & Pre-test for Rheumatoid Arthritis) ** Answer as many questions as you can (You may skip the questions if you don't know the answer.)*

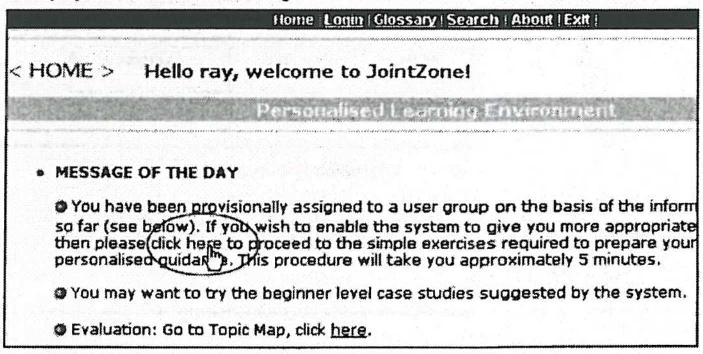
2. Login

   - Go to the web site and **login** to the web site using the following.

     Username: ____________
     Password: ____________

3. User Information capturing

   - After login, follow the link 'Enter here' to enter the web site. On the 'Message of the day', you will see the first message which reads:



   - Follow the link 'here' on the screen and **complete the exercises (1 reading speed evaluation and 2 sets of questionnaires)** prompted to you. **Return to this paper** when done.

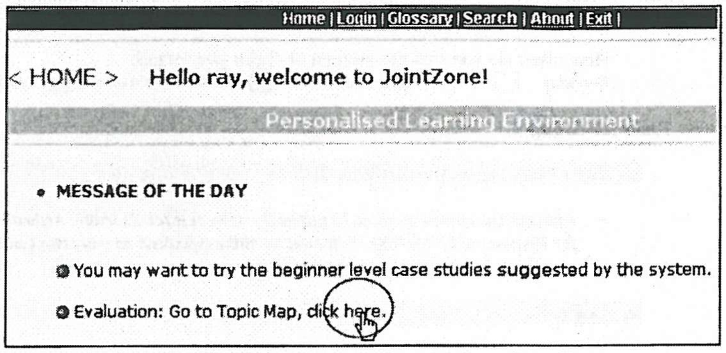
A1- 1

FIGURE E.1: Tasks for group 1

Adaptive Hypermedia Research

4. Use the Topic map

- You should now see the 'home' page on the website, you will see a link on the message of the day which says:



- Follow this link to go to the ***Topic Map***.
- Use <u>ONLY</u> this map to answer all the 10 questions on **paper C** (*Post - test for Psoriatic Arthritis*). It is the same set of questions as you have seen before, but this time you may use the topic map to get the answers. *Pick 'Psoriatic* Arthritis' as your reading topic on the map. ** Remember to jot down the time start and time finish.

- When you are done, answer the following questions (Tick your answer.)

i. I found the topic map helped me locate information.

Agree	Not sure	Disagree

Any comments?

ii. I found the topic map easy to use.

Agree	Not sure	Disagree

Any comments?

AI- 2

FIGURE E.2: (continue)Tasks for group 1

Adaptive Hypermedia Research

5. Read up on Rheumatoid Arthritis

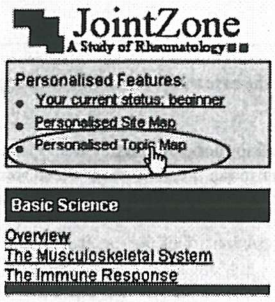
- Return to the 'home' page. Using the web site, read about '***Rheumatoid Arthritis***'. You may start with the following pages but are encouraged to look at others. (Do not spend too much time here, five minutes would be ideal)

(heading >> subheading >> Title) as appear on table of content

- o Rheumatic Disorders >> Inflammatory Disorders >> Rheumatoid Arthritis-Articular Disease
- o Approach To Patient >> Musculoskeletal Examination >> The Elbow

6. *Personalised* Topic Map

- On the table of content, in a box that says 'Personalized features', follow the link to the ***Personalised Topic Map***.



- Use this map to answer the 10 questions on **paper D** – *Post-test on Rheumatoid Arthritis*. Again, you have seen these questions before, but this time you may use the *Personalised Topic Map* to help you with the answer. *Pick 'Rheumatoid Arthritis' as your reading topic on the map . ** Remember to jot down the time start and time finish.*
- When you are finished, tick how you feel about the statement below.

i. I found the reading gauge indicator on the personalised topic map helpful.

Agree	Not sure	Disagree

Any comments?

____

AI- 3

FIGURE E.3: (continue)Tasks for group 1

Adaptive Hypermedia Research

7. Case study

- In this task, you need to step through ONE of the case studies on the web site. Follow the instructions on each screen in the case study. As you do so, make a note in the space below about anything in the case study that isn't clear or that you don't understand that you might wish to read more about.
- The link to the case study can be found on the table of content. ** Select the level indicated by the red stars.

Notes for further reading:
e.g What is esr?

- At the end of the case study, jot down how many points you have collected/scored: ________

- Follow the link to further reading.
- You will come to the 'Reading room'. Read some of the suggested documents to see if this further reading helps and provide some answers to the 'notes' you have made above.
- What's your opinion? Tick the statement that is most appropriate for you.

i. The reading room helped me to find out *more* information about the case study I have just done.

Agree	Not sure	Disagree

Any comments?

____

ii. I would be likely in future to use the reading room after each case study.

Agree	Not sure	Disagree

Any comments?

____

iii. The number of links suggested in the reading room were (tick one)

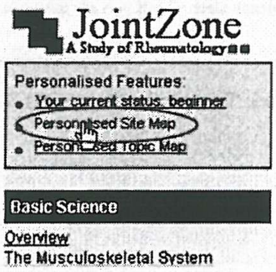
AI- 4

FIGURE E.4: (continue)Tasks for group 1

Adaptive Hypermedia Research

a. Just right for me ☐
b. Not enough for me ☐
c. Too many for me ☐

8. Personalised Site Map



- On the personalized features box (on top of the table of content), follow the link to the personalized *site* map.
- Browse the web site using the site map, noting the icons that mark each document title. The icon tells you whether the page has been read very little, if at all (low), partially read (medium), or well read (high).
- What's your opinion? Tick the statement that is most appropriate for you.

i. To complete the task in No. 4, I would prefer to use:

a. the personalised site map ☐

b. the table of contents ☐

c. no preference which I use ☐

Any comments?

____

ii. I think the personalised site map was useful to navigate the site.

Agree	Not sure	Disagree

Any comments?

____

iii. I think the reading gauge marker beside each document was helpful to determine which documents I have already read.

Al- 5

FIGURE E.5: (continue)Tasks for group 1

Adaptive Hypermedia Research

Agree	Not sure	Disagree

Any comments?

Or please state why if you are not sure.

Please click **'Exit'** on the menu to logout from the website.

~Thank you for your cooperation~
~All Information given will remain confidential ~

AI- 6

FIGURE E.6: (continue)Tasks for group 1

Adaptive Hypermedia Research

A2

Fill in your personal details:

Name: ____________________

Year of Study: ______________ Email: ____________________

How often do you surf the Internet or check your email:

Everyday ☐ *once/twice a week* ☐ *once/twice a month* ☐ *rarely/never* ☐

Tasks for Group 2:

1. **Paper-based prior knowledge test:**
   - **Attempt the questions given in paper B – *(Pre-test for Psoriatic Arthritis & Pre-test for Rheumatoid Arthritis. ** Answer as many questions as you can. (You may skip the questions if you don't know the answer.)***
2. **Login**
   - Go to the web site and **login** to the web site using the following.

     Username: ______________

     Password: ______________
3. **User Information capturing**
   - **After login, follow the link 'Enter here' to enter the web site. On the 'Message of the day', you will see the first message which reads:**

     Home | Login | Glossary | About | Exit |

     < HOME > **Hello angie, welcome to JointZone!**

     - **MESSAGE OF THE DAY**

     You have been provisionally assigned to a user group on the basis o so far (see below). If you wish to enable the system to give you more a then please click here to proceed to the simple exercises required to pr personalised guidance. This procedure will take you approximately 5 mi

     Evaluation: Go to *Topic* Map, click here.

     Evaluation: Go to Personalised *Site* Map, click here.
   - **Follow the link 'here' on the screen and complete the exercises (1 reading speed evaluation and 2 sets of questionnaires) prompted to you. Return to this paper when done.**

A2 1

FIGURE E.7: Tasks for group 2

Adaptive Hypermedia Research

4. Use the web site.

- Answer all the 10 questions on **paper C** (*Post - test for Psoriatic Arthritis*). It is the same set of questions as you have seen before, but this time you may **use the web site** to help you with the answers. You may find the table of content helpful to find your way around.

5. Read up on Rheumatoid Arthritis.

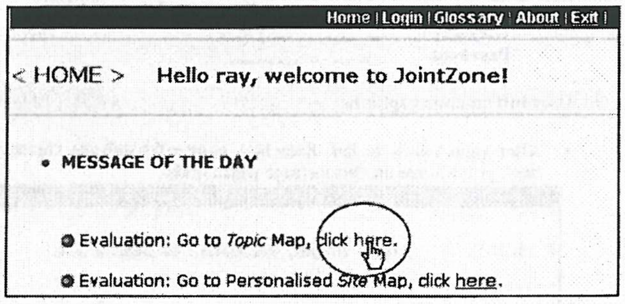
- Return to the 'home' page. Using the web site, **read** about ***'Rheumatoid Arthritis'***. You may start with the following pages but you are encouraged to look at others. (Do not spend too much time here, five minutes would be ideal)

(heading >> subheading >> Title) as appear on table of content

- **Rheumatic Disorders >> Inflammatory Disorders >> Rheumatoid Arthritis-Articular Disease**
- **Approach To Patient >> Musculoskeletal Examination >> The Elbow**

6. Using the Topic Map to look for information.

- On the 'home' page, follow the link to the *Topic Map*.



- Use this map to answer the 10 questions on **paper D** – ***Post-test on Rheumatoid Arthritis.*** Again, you have seen these questions before, but this time you may **use the *Topic Map*** to help you with the answer. *Pick 'Rheumatoid Arthritis' as your reading topic on the map.* *****Remember to jot down the time you start and the time you finish.***
- When you are done, answer the following questions (Tick your answer.)

a. I found the topic map helped me locate information.

Agree	Not sure	Disagree

Any comments?

A2 2

FIGURE E.8: (continue) Tasks for group 2

Adaptive Hypermedia Research

b. I found the topic map easy to use.

Agree	Not sure	Disagree

Any comments?

7. Case study

- In this task, you need to step through **ONE** of the case studies on the web site. Follow the instructions on each screen in the case study. As you do so, make a note in the space below about anything in the case study that isn't clear or that you don't understand that you might wish to read more about.
- The link to the case study can be found on the table of content. ** Select from one of the three levels appropriate to your level.

Notes for further reading:
e.g. What is esr?

- At the end of the case study, jot down how many points you have collected/scored: ________
- Follow the link to' ***further reading'***.
- You will come to the **'Reading room'**. Read up on some of the suggested documents to see if this further reading helps and provides some answers to the 'notes' you have made above.
- What's your opinion? Tick the statement that is most appropriate for you.

a. The reading room helped me find out *more* information about the case study I have just done.

Agree	Not sure	Disagree

Any comments?

A2 3

FIGURE E.9: (continue) Tasks for group 2

Adaptive Hypermedia Research

b. I would be likely to use the reading room after working through a case study.

Agree	Not sure	Disagree

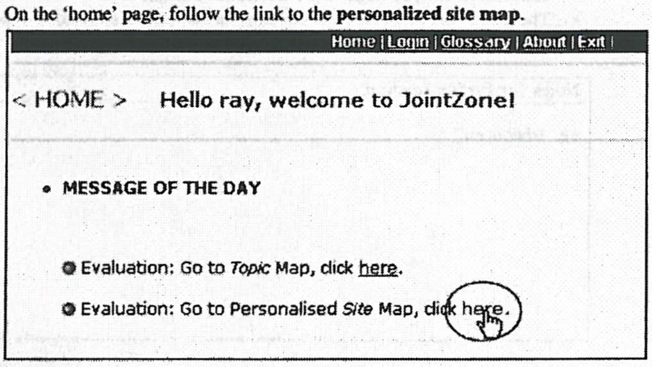
Any comments?

c. The number of links suggested in the reading room were (tick one)

i. Just right for me ☐
ii. Not enough for me ☐
iii. Too many for me ☐

8. Personalised Site Map

- **On the 'home' page, follow the link to the personalized site map.**



- **Find out what the reading gauge is by clicking on 'explain'.**
- **Browse the web site using the site map, pay attention to the reading gauge that marks each document title. The icon tells you whether the page has been read very little, if at all (low), partially read (medium), or well read (high).**

- **What's your opinion? Tick the statement that is most appropriate for you.**

a. To complete the task I was given in No. 4, I would prefer to use:

i. the personalised site map ☐
ii. the table of contents ☐
iii. no preference which I use ☐

Any comments?

A2 4

FIGURE E.10: (continue) Tasks for group 2

Adaptive Hypermedia Research

b. I think the personalised site map was useful to navigate the site

Agree	Not sure	Disagree

Any comments?

____

c. I think the reading gauge marker beside each document was helpful to determine which document I have already read.

Agree	Not sure	Disagree

Any comments?

____

Or please state why if you are not sure.

____

Please click 'Exit' on the menu to logout from the website.

~Thank you for your cooperation ~
~All Information given will remain confidential ~

A2 5

FIGURE E.11: (continue) Tasks for group 2

B

***Pre*-test: Psoriatic Arthritis**

****** *You may skip the questions if you don't know the answer.***

1. Can you name two different patterns of psoriatic arthritis

2. Name one classic site on the body where psoriasis may be found.

3. Name two other sites on the body where you should look for psoriasis.

4. What is the relationship between psoriasis and psoriatic arthropathy - does the severity of the arthritis reflect the severity of the skin condition?

   Yes / No:

5. Psoriasis in the scalp can be confused with another skin condition. Can you name it?

6. What are the nail manifestations of psoriasis?

7. When psoriatic arthropathy affects a digit, this is often given a distinctive descriptive term. What is it?

8. What is the incidence of psoriasis in the population? (Please give a percentage figure)

9. Which usually starts first? Psoriasis or psoriatic arthritis?

10. If a patient is suspected of having psoriatic-type arthritis but doesn't have the skin rash at the time - what term is given to the arthritis?

continue →

B- 1

FIGURE E.12: Pre-Test for task 1 (Psoriatic Arthritis) for both groups

Pre-test: Rheumatoid Arthritis

1. What is the characteristic pattern of joint involvement in rheumatoid arthritis?

2. What is responsible for the swelling of joints in rheumatoid arthritis.

3. What may be partly responsible for the development of carpal tunnel syndrome in rheumatoid arthritis?

4. What other swelling may also be found at the site where rheumatoid nodules are most commonly found?

5. Why may rheumatoid nodules become painful?

6. What sign of liver disease may be found in patients with rheumatoid arthritis who don't necessarily have liver impairment?

7. What swellings on the knuckles are sometimes mistaken for rheumatoid nodules?

8. When fibrosing alveolitis occurs in rheumatoid arthritis, which part of the lung is usually affected?

9. What do nail fold infarcts indicate?

10. In which internal organs can rheumatoid nodules sometimes be found?

B- 2

FIGURE E.13: Pre-Test for task 2 (Rheumatoid Arthritis) for both groups

***Post*-test: Psoriatic Arthritis** **C**

Write down the time shown on the left-hand lower corner of the computer screen:
Time Start: **__________________(i.e. 2:35 pm)**

1. Can you name two different patterns of psoriatic arthritis

2. Name one classic site on the body where psoriasis may be found.

3. Name two other sites on the body where you should look for psoriasis.

4. What is the relationship between psoriasis and psoriatic arthropathy – does the severity of the arthritis reflect the severity of the skin condition?

Yes / No

5. Psoriasis in the scalp can be confused with another skin condition. Can you name it?

6. What are the nail manifestations of psoriasis?

7. When psoriatic arthropathy affects a digit, this is often given a distinctive descriptive term. What is it?

8. What is the incidence of psoriasis in the population?(Please give a percentage figure)

9. Which usually starts first? Psoriasis or psoriatic arthritis?

10. If a patient is suspected of having psoriatic-type arthritis but doesn't have the skin rash at the time - what term is given to the arthritis?

Again, write down the time shown on the computer screen.
*Time finish:*__________________(i.e. 3:15 pm)

FIGURE E.14: Post-test for task 1 (Psoriatic Arthritis), for both groups.

***Post*-test: Rheumatoid Arthritis** **D**

Write down the time shown on the left-hand lower corner of the computer screen:
Time Start: ____________________

1. **What is the characteristic pattern of joint involvement in rheumatoid arthritis?**

____

2. **What is responsible for the swelling of joints in rheumatoid arthritis.**

____

3. **What may be partly responsible for the development of carpal tunnel syndrome in rheumatoid arthritis?**

____

4. **What other swelling may also be found at the site where rheumatoid nodules are most commonly found?**

____

5. **Why may rheumatoid nodules become painful?**

____

6. **What sign of liver disease may be found in patients with rheumatoid arthritis who don't necessarily have liver impairment?**

____

7. **What swellings on the knuckles are sometimes mistaken for rheumatoid nodules?**

____

8. **When fibrosing alveolitis occurs in rheumatoid arthritis, which part of the lung is usually affected?**

____

9. **What do nail fold infarcts indicate?**

____

10. In which internal organs can rheumatoid nodules sometimes be found?

____

Again, write down the time shown on the computer screen.
Time finish: ____________________

FIGURE E.15: Post-test for task 2 (Rheumatoid Arthritis), for both groups.

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