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FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

School of Electronics and Computer Science

Links Personalisation with Multi-Dimensional Linkbases

by

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ABSTRACT

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Adaptive hypermedia has provided a way information can be presented online. Based on adaptive presentation and adaptive navigational support, a static page can now be dynamically personalised for an individual user. Users who possess different needs, interests and background knowledge can now be provided with a different presentation of the same information. Many frameworks for adaptive hypermedia systems and applications have been proposed that use different strategies.

This thesis proposes a new approach for the presentation and personalisation of links based on the idea of a multi-dimensional linkbase. It is the notion that describes a single linkbase that contains links annotated with metadata that place the links in several different contextual dimensions at once. These sets of links signify different dimensions of expertise of the user and are encoded to condition the visibility of links. This work builds upon the implementation of FOHM and Auld Linky at Southampton University. To provide users with control over the personalisation of their links, the users are provided with navigational tools for the presentation of these links. The presentation of the links depends on the preferences of the users and the linkbases they have enabled and disabled. This facilitates flexibility and reduces the user syndrome of ‘too many-irrelevant-additional links’.

Four straightforward adaptive systems have been developed to demonstrate the diversity of the link service approach, and in particular the concept of a multi-dimensional linkbase, which has been applied into a Web-based prototype, an inquiry-led personalised navigation system. This thesis also documents the formal evaluation studies undertaken, which demonstrates that such a proposal is practicable and meaningful to a user.

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Chapter 1 Introduction

The advent of Adaptive Hypermedia (AH) enhanced how information could be presented and personalised online. It is an area of research which attempts to reduce cognitive overload and the disorientation problem by assisting users in their navigation and decreasing their time in finding the right information. Based on its adaptive presentation and adaptive navigation support (Brusilovsky, 1996; Brusilovsky, 2001), a (static) page can be viewed differently in response to individual users. Users with different background knowledge and interests are presented with different portions of the same information, or different information adapted accordingly, in the form of contents and navigational links. The user model, a model to capture users' information about their initial interests and their dynamic browsing behaviour, is one of the major components for the personalisation and adaptation to take place. Many frameworks for AH systems and applications have been proposed and AH research has also been recently extended to cover issues such as shareability and reusability and the Semantic Web (De Bra *et al*., 2004; Maneewattana *et al*., 2005).

1.1 Overview of this Research

The terms hypertext and hypermedia are now interchangeable. A hypermedia system is one that contains information that can be presented in any textual or pictorial form, and this information is inter-related by means of linking and indexing. The purpose of hypermedia is ideally to provide access to, and manipulation of, information (Lowe and Hall, 1999). The goal of hypermedia is rather different from that of most other types of information system in that it does not place emphasis on the facts about what the data is, nor what it consists of, nor how the data flows and is processed, but focuses particularly on the means whereby the information can be structured and accessed (Avison and Fitzgerald, 1995; Lowe and Hall, 1999; Bailey and Hall, 2000). In this environment, users are provided with the freedom to explore and navigate the information space through links presented to them. In an educational context, it is claimed that the users have more control over the content presented to them and they can organise their own learning sequence (Laurillard, 1987; Ng *et al*., 2002a).

The Open Hypermedia (OH) subgroup of the hypertext community originated in the late 1980s. They viewed hypermedia as a system providing services for integration of information and processes in a distributed heterogeneous environment where there are no distinctive access rights between the reader and the author (Davis *et al*., 1993). The underlying principle of the OH concept is that links are separated from the body of a hypermedia document and stored independently in a link database (linkbase). A linkbase can be therefore viewed as a database of link structures. An example of a link structure is one which maintains information about the source and destination of that particular link. Within the link-oriented view of hypermedia, a link service – an application to provide link functionality to other applications – is required. This link service operates on demand. One technique to provide such functionality is *link augmentation*. This is defined as *a technique whereby external links are inserted directly into the body of a document* (Bailey *et al*., 2001). However, the common difficulty with link augmentation is that every significant word on a page can become a link and this can cause a problem of link overload. This thesis proposes a concept which reduces this problem of too many additional links being inserted into a page, as discussed later.

Over a number of years of research, the OH community has proposed generalised models such as Intermedia (Yankelovich *et al*., 1988), Sun's Link Service (Pearl, 1991), Chimera (Anderson *et al*., 1994) and Hyper-G (Andrews *et al*., 1995), and protocols to provide interoperability between systems. Researchers at the University of Southampton evolved several systems: Microcosm (Davis *et al*., 1993), an OH system in which users were provided with dynamic and cross-application hyperlinks; the Distributed Link Service (DLS) (Carr *et al*., 1995), which widened the Microcosm philosophy to incorporate the newly-arrived Web model and supported multiple users in a distributed environment; and the Fundamental Open Hypermedia Model (FOHM) (Millard *et al*., 2000), an OH model with contextual structures used to describe the structure of hypertext objects and their associations between data in different domains of hypertext systems.

In parallel to the hypermedia and OH research, Tim Berners-Lee, the inventor of the Web, had incorporated the idea of hypertext within the Internet (Berners-Lee, 1991). The arrival of the Web changed researchers' interests towards implementing Web-based applications. The Web has become the graphical user interface of the Internet and also a fundamental platform for development and distribution of today's information. When we now want to know about something, everyone's first choice is to use a search engine to look for that particular information on the Web. The Web hosts billions pages of original information and the 'Google' search engine announced the increasing of its index to 8 billion pages in November 2004 (Sullivan, 2005). It is claimed that the clarity of the hypertext model behind the Web has led to its success (Bailey, 2002). Nevertheless, although the Web provides users with navigation facilities using hypermedia links and search engines, its full potential is yet to be discovered and made available. One of the shortcomings of the Web as a hypermedia application is that most links are embedded in the source document, and that there is no support for associative linking (Hall, 2000). Embedding links in the source document results in the problem of updating and maintaining materials, which users observe as broken links. The lack of support for associative linking leads to the difficulty in finding the right information. There have been a number of research attempts to solve these shortcomings, two of which are *open hypermedia* and *adaptive hypermedia*.

Adaptive Hypermedia (AH) is also a sub-discipline of hypertext research. This area of research has aimed at improving the usability of hypermedia applications by solving the above-mentioned problems as well as the problem caused by the free-exploration environment. It is an approach that takes into consideration individuals' differences, and provides a selection of adapted contents and links uniquely tailored to each user's needs.

1.2 Objectives and Scope

The link augmentation technique offers the advantage that links can be created, added, or modified without the original document being affected, and likewise the text can be modified or moved around, while the original links still function correctly (Hughes, 2000; Bailey *et al.*, 2001). However, the main problem with this technique is that most existing applications base their link insertion on replacing known or visited keywords or phrases in a document, which results in every keyword becoming a link. As a consequence, this inevitably creates problems such as 'prolific linking' (Carr *et al.*, 2002) and 'out of place' links (El-Beltagy *et al.*, 2002).

In addition, although AH techniques assist users with personalisation of contents and links, one of the criticisms of adaptive systems is that users are prevented from having control over the system's behaviour (Tsandilas and schraefel, 2004). That is, the user does not always understand what and why the system is adapting the content and links.

The objective of this work is first to present a new application of the link augmentation technique; and secondly to facilitate user control over a personalised system. This new framework uses the concept of a multi-dimensional linkbase with direct manipulation. On the one hand, the notion of a multi-dimensional linkbase is an approach where different groups of links created and stored in a single linkbase symbolise different dimensions of expertise and these links are encoded to condition the visibility of links based on an individual user profile. On the other hand, the concept of direct manipulation (Schneiderman and Maes, 1997) is a user interface technique which provides users with the control over the manipulation of objects presented by applications/systems. By joining the notions of a multi-dimensional linkbase and direct interaction, not only will the user be equipped with some degree of control over the personalisation of links, allowing the user to have a better understanding of the behaviour of the adaptive system, the user will also not experience the difficulty of having too many navigational links inserted into a page (as encountered in conventional link augmentation process, Bailey *et al*., 2001).

For this proposal, a prototype system called an Inquiry-led Personalised Navigation System (IPNS) was developed to prove the applicability and usefulness of the concept proposed. IPNS is described as a Web-based personalised navigation system presenting users with 'inquiry-led' navigational tools for link presentation and personalisation. The term *inquiry-led* is used to denote the inquiring action and that these inquiry tools can function on demand to support more navigational strategies when needed. The idea of the Web-based application is to present a platform for exploration as well as systematic navigation. Although it is implemented in a specific domain, it can also be enhanced to facilitate shareability and reusability issues when further developed into a Web service environment.

The initial stage of this work is primarily based on the link augmentation process, and the later stage heavily involves the application of the concept of a multi-dimensional linkbase.

Formal evaluation studies are also another objective of this work, in order to investigate whether the proposed concept and its prototype system developed is seen as contributing, applicable, and meaningful to the user.

1.3 Contributions

This thesis documents several key contributions made to the field of adaptive hypermedia and open hypermedia, particularly for Web-based personalised navigation systems.

The primary contribution this work makes to the two fields is the proposed concept of a Multi-Dimensional Linkbase (MDL) for link presentation and personalisation, an idea where set of links created and stored in a single linkbase are representative of different expertise dimensions, and the representations of links come from these different expertise dimensions and their different expertise levels based on the user model. MDLs, when used to support adaptive behaviour, enable users to perceive the working behaviours of the adaptive system more easily than other adaptation approaches. Through this better understanding of the adaptive behaviours, a user can make adaptation better work for them and hence it can help to reduce the link overload problem.

Secondly, the integration of the MDL concept into a Web-based personalised navigation system provides adaptive functionality which can be practically applied to any existing system with provision of link augmentation and the link server. The user can experiment with and tailor the system at runtime to choose the best presentation of links to suit their preference, by either enabling or disabling the contextual dimensions.

In addition, the work uses taxonomy-based ontology in FOHM structures to provide semantic representation of concepts to assist the process of querying for a concept.

Finally, the work presents formal evaluation studies which were conducted to confirm whether our concept is applicable and meaningful to users and to establish what is the extent and limit of this understanding.

1.4 Document Structure

This thesis describes a concept of a multi-dimensional linkbase and its application which resulted in the development of a Web-based personalised navigation system. Early chapters of this work specify the literature review of hypermedia, adaptive hypermedia, and open hypermedia, which are primarily key research issues, followed by the initial experiments of the author. Later chapters document a concept of a multi-dimensional linkbase (MDL), the inquiry-led navigation system, and the integration of the inquiry-led personalised navigation system (IPNS) with the MDL concept, together with the system and user evaluation of the implemented prototype.

Chapter 2 gives an overview of literature relating to this work in the area of hypermedia, its history and concepts, and examples of hypermedia systems. Then the field of adaptive hypermedia is presented with its various adaptation techniques, together with examples of some established systems and the highlights of the research direction.

Chapter 3 presents the field of open hypermedia, its concepts, the link service approach, the link augmentation process, a technique resulting from the open hypermedia community, and the Fundamental Open Hypermedia Model (FOHM) which provided the openness and interoperability between different domains of hypertext systems. The chapter also depicts attempts to introducing open hypermedia research to the field of adaptive hypermedia, as well as a brief introduction to ontological hypermedia.

Chapter 4 documents the author's early experiments concerning link augmentation with Auld Linky, a link server, one of the main technologies of this work. In addition, this chapter describes the early integration of the AHA! system with Auld Linky, and the implementation of different dimensions in linkbases (DDL) for the cookery domain. All of the experiments have provided the grounding and experience essentially for the core of the thesis.

Chapter 5 introduces the concept of a multi-dimensional linkbase (MDL) and the inquiry-led navigation system which are integral to the thesis. A framework is proposed. The chapter also explains the requirements that make the integration possible.

Chapter 6 details the development of a Web-based inquiry-led personalised navigation system (IPNS) as the result of the integration of the multi-dimensional linkbase concept and the inquiry-led navigation system. The adaptive techniques applied in the proposed system will then be described, as well as the provision of other personalised features the prototype website has to offer.

Chapter 7 presents a fundamental background of the usability and evaluation, their definitions, methods and techniques of evaluation of user interface, hypermedia and adaptive hypermedia. The chapter also places an emphasis on the evaluation approach of the prototype developed.

Chapter 8 provides a heuristic evaluation and a user-centric evaluation of the system presented and their results. The hypotheses are introduced and tested. The statistical analysis is documented. The chapter concludes with a discussion of the experimental results of the evaluation.

Chapter 9 concludes by summarising this work on the concept of a multi-dimensional linkbase. The chapter also documents some possible future directions in which this work can be extended.

1.5 Declaration

This thesis describes the research undertaken by the author while working within a collaborative research environment. Initial work by the author, which centred on the link augmentation technique, resulted in the development of three different straightforward Web-based AH systems. The central part of this work presents a concept of a multi-dimensional linkbase and its application, a Web-based prototype system, built upon the implementation of FOHM and Auld Linky. In addition, formal evaluation studies of the proposed concept and its application were undertaken.

This report documents the original work of the author, including concepts and philosophies, the design methodology, the conceptual model, and the front-end interaction and implementation. To implement the idea developed in this thesis a number of existing technologies were used. The back-end system for link augmentation, Proxy (an in-house Java proxy) and Auld Linky – a contextual link server, originally developed as part of the EQUATOR project by Dr David Millard, Dr

Danius Michaelides, and Dr Mark Weal (Michaelides *et al.*, 2001). Further enhancement of Proxy and Auld Linky was initially guided coding, and the later modification was made by Dr Christopher Bailey. The stemming algorithm for the 'follow link' option of the IPNS prototype system was developed by Samhaa El-Beltagy for the QuIC project (El-Beltagy, 2001). The early integration between the AHA! system and Auld Linky, which was used in the Thai-Dutch cookery system, was developed in conjunction with Koen Aben, an internship student from Eindhoven University of Technology. Lastly, the following publication has been produced in the course of undertaking this research:

Longpradit, P., Bailey, C., Hall, W., and Wills, G., 2006. *Personalised Navigation System with Multidimensional Linkbases*. In Wade, V., Ashman, H., and Smyth, B. (Eds.) Proceeding of the Fourth Adaptive Hypermedia and Adaptive Web-based Systems International Conference, AH 2006, Dublin, Ireland, June 2006. LNCS 4018, pp 293-297.

Chapter 2 Background

2.1 Introduction

The following two chapters present the background related to this work. The first chapter begins with the history of hypermedia, its fundamentals, and examples of hypermedia systems and applications. The second half of this chapter documents the field of Adaptive Hypermedia (AH), a research area which attempts to increase the functionality of hypermedia applications by using its techniques to personalise information in relation to individual users. The varied adaptation techniques are described, together with some chosen well-established AH systems and applications that have been developed. The chapter also documents the AH research direction.

2.2 Hypermedia

The terms hypertext and hypermedia are now commonly used interchangeably. However, originally, hypertext is meant to be used for the text only version, whereas hypermedia included other types of media, such as image, video and audio (W3C, 1992).

Hypermedia is a concept that allows authors to structure information as a non-linear network of different forms of material. With a graphical user interface, users can browse through these materials in a variety of ways. Its key concept is a database of *nodes*, *links* and *anchors* and their *linking mechanisms* (Halasz and Schwartz, 1994). *Nodes* are entities which contain a collection of information in the forms of text, image, audio or video. On the other hand, *links* represent an association between nodes and support sequential and non-sequential navigation from one node to another, each of which is composed of the *link source* and the *link destination*. Link sources are the starting points of navigation, most of which can be a particular part of a node such as keywords, phrases, or images, whereas link destinations are desired places the links point to, for instance, a new node or even a part or whole of the originating node. An *anchor* denotes a link on a node. This includes annotated texts or ‘hotspots’, buttons, images, or any designated items which can be a link's source or destination. Finally, *linking mechanisms* allow each node to be connected to other nodes to form a hypermedia network. These linking mechanisms can vary from 'simple linking', i.e. one link source to one destination, to 'multi destinations linking', i.e. linking one source to many destinations, or many sources to one link destination (Lowe and Hall, 1999; Leggett and Schnase 1994).

The primary advantage of hypertext is said to be that it permits associations of textual information as well as images and media other than text to be linked non-sequentially in a variety of ways, which results in the ability to follow these associations and search for related materials more rapidly than the traditional printed medium could offer. Unlike the textbook or printed documents, the user can easily browse and navigate this collection of information back and forth and simply leave out or skip through irrelevant and unwanted materials.

2.2.1 History of Hypermedia

The history of hypermedia began with Vannevar Bush's Memex, 'Memory Extender' (Bush, 1945). Bush was one of the pioneers of hypertext who highlighted the idea of linking related items of information and using trails to discover relevant information, although his ideal system was never implemented (Hall, 2000). However, his idea inspired other researchers. Engelbart (1963) set up his research lab to expand human capabilities and processing which resulted in his oNLine System (NLS), a hypertext system (although the term hypertext was not coined until later) that applied the hypertext concept to storage and retrieval of electronic documents in the form of digital libraries. He invented the mouse pointing device to associate the interaction with the computer, as well as other user interfaces such as window-based interface, e-mail functionality and on-screen video teleconferencing. His NLS's demonstration at the Fall Joint Computer Conference in San Francisco is still acknowledged as "the mother of all demos". Nelson (1965) first defined the term "hypertext" as a means of supporting the reading and writing of non-sequential text, and later the term hypermedia was also invented by him. As part of his Xanadu project, he proposed the idea that information could be stored and retrieved in non-sequential manner by the use of linking mechanism. Since then the hypermedia community has focused on systems, guidelines, frameworks and theories about designing and authoring, presenting, and accessing this interconnected information network (Bieber *et al*., 1997). As a consequence, there have been many hypertext systems and applications developed and the hypertext research has effectively swung from designing to evaluation of hypertext systems. A comprehensive survey of hypertext and early hypertext systems and applications can be found in Conklin (1987).

2.3 Adaptive Hypermedia

Adaptive hypermedia (AH) is an area of research that attempts to increase the functionality of hypermedia applications by individualising their presentation in relation to individual users (Brusilovsky, 1996). It is a field that applies the research in user modelling and artificial intelligence to hypertext. Despite hypermedia applications enabling users to browse and navigate between different sources of information, traditional hypermedia systems lead to usability problems in terms of *cognitive overhead* (Conklin, 1987), or *content comprehension* (De Bra and Calvi, 1998a) and *disorientation* or *lost in space* (Conklin, 1987) due to the fact that there is too much information and too many possible navigational paths that a user can follow, and that documents are so cross-referenced that users can lose their location and direction. In addition, conventional hypermedia applications fail to take into consideration users with different backgrounds and goals, which have great impact on the way they navigate the hypertext system or the Web and their need for particular information (Brusilovsky, 1994; Höök, 1998; Hall, 2000). It is apparent that users with different backgrounds and knowledge require different portions of information. Therefore, the use of adaptive techniques is aimed at providing users with different pieces of the same or dissimilar information and different navigational links, depending on the user profile. For instance, a user who is a novice might require descriptive information, whereas an advanced user may need only concise or more summarised information. To make adaptation possible, the user profile, a model to captures information about users, is one of the crucial components in any AH system.

Some researchers made a distinction between the terms personalise, adaptable, and adaptive. For instance, De Bra (2000) pointed out that an adaptive system is a system where the user's preferences can be inferred automatically after a number of page accesses in the browsing process, whereas an adaptable system is a system where the user is offered an explicit choice for presentation via questionnaires or forms to attain his or her resulting page and this setting is only changed when the user makes changes. Similarly, Hothi (2001) viewed an adaptive system as a system where the adaptation occurs dynamically during the session consequent on the end user's behaviour, whereas a hypermedia system is considered adaptable when the end user has the facility to change its functionality and characteristics. In addition, Wadge and schraefel (2001) referred to adaptive hypermedia as systems where the delivery of user-specific content is dependent on a user model (system-determined), whereas they observed adaptable hypermedia as systems where users can adapt the hypertext by choosing from a range of parameters according to their needs (user-determined).

By contrast, Ohene-Djan *et al.* (2003) instead considered the distinction between personalisation and adaptation, in which the former is referred to as a user-initiated process whereas the latter is regarded as system-initiated action. In this paper, the author has chosen the term personalisation to refer to a system that depends on the user profile to sustain the system's presentation and that the user takes the initiative in the adaptation process.

From a different perspective, Millard *et al*. (2003) commented that AH research has taken a deterministic approach to the design and authoring of hypertexts. By deterministic, he means that authors are aware of the navigational paths available to the user. The author defines the possibility of adapted contents and links at design time and the user attains the dynamic results of the adaptation process at run time based on his or her user profile. Henze (2005) similarly stated that the development of AH systems has been so far in a *closed world* setting. By this, she claimed that these systems operate on a fixed list of resources created by the system developers at design time.

Adaptive hypermedia is now over ten years old and the AH research has been extended to cover issues such as shareability and reusability and the Semantic Web. Nevertheless, the AH techniques and methods used for adaptation still arise and provide a basis for personalisation and adaptation in the WWW. The following sections present the concept of AH as well as its techniques employed to make personalisation and adaptation possible.

2.3.1 Adaptive Hypermedia System

Brusilovsky (1996) defined three criteria that a system must exhibit if it is to be regarded as an AH system. First, the system should be a hypertext or hypermedia system based on a domain. A domain model is a representation of the content of knowledge in a chosen subject the system developer aims at describing or delivering. It particularly describes how the content of the domain is organised and interconnected. De Bra *et al*. (1999) described three types of concept: *atomic concepts or fragments*, that is, the smallest information units; *pages* (interconnection of atomic concepts or fragments); and *abstract concepts* or larger units of information.

Secondly, the system should consist of a user model. User modelling (UM) is the process of capturing knowledge about users which can be applied to represent their state of action or progress. AH systems rely heavily on user profiling which can be constructed either the first time the user logs on to the site and provides explicit information about themselves, or after the user has browsed the pages for a reasonable period of time and the system implicitly observes the user's behaviour. The user modelling is an essential feature in any AH application for making adaptation decisions. Without it, information or instructional materials cannot be personalised to the individual user, and all users would be presented with the same contents and links. The UM is in fact another field in its own right. Section 2.3.2 gives an overview of what a user model is, and what information could be contained in user modelling.

Finally, the (AH) system utilises the domain model and the user model to adapt various aspects of the system to the user.

2.3.2 User Modelling

A user model is a representation of information about users that can be traditionally accessed by retrieve, insert and update processes. This information includes *user characteristics* (i.e. user's goal/tasks, level of expertise, background, hyperspace experience, preferences, interests, and individual traits – a group name for user features that together define the user as an individual); *user behaviours* (user's performance indicators, user's trail or browsing history); and *environment* (i.e. user location, platform, direction of sight, and movements) (Hothi, 2001; Bailey, 2001; Brusilovsky, 2001). There are two ways of capturing user information: *explicit* and *implicit*. The former means that the user information is obtained from users themselves when they first register with the system or from what the user has gained from the on-line pre-test, questionnaires and so on (user characteristics). The latter involves the process of silently observing and capturing user information while users are working throughout sessions (user behaviour and environment). AHA!, for instance, captures the user's (domain) expertise implicitly.

Moreover, UM can be static or dynamic (Hothi, 2001). By static, is meant that the system will use information provided by the user when it was first created throughout the interaction. In contrast, dynamic user modelling caters for user progress and behaviour and uses this information to update the user model continuously.

2.4 Adaptation Techniques in AH

To create an AH system, the questions needing answers are: what components of the information are to be presented (contents or links), and what user information is to be captured in order to construct the user model (user modelling). Brusilovsky (1996) distinguished two main types of adaptation techniques which any adaptive hypermedia system can be equipped with: *adaptive presentation* (content-level adaptation), and *adaptive navigation support* (link-level adaptation).

2.4.1 Adaptive Presentation

Adaptive presentation refers to adapting the presentation of the content of a hypermedia page before presenting it to the user, depending upon the user's goals, knowledge, and needs (Brusilovsky, 1996). A content or concept is a part of the whole information that depicts an item of knowledge (De Bra, 1999). As users vary in their level of understanding and background knowledge, the goal of adaptive presentation is to elicit that difference and to present the right level of content to a particular user. For instance, novices will be provided with basic concepts, whereas advanced users will be presented with more complicated and additional information.

De Bra (2000) considered two different aspects to this term. First, the same information can be delivered to users in different ways in relation to media selection, the level of difficulty of the presented information, and presentation style (concise or detailed). Secondly, the same page may present different information to different users depending on whether the users should be offered additional, prerequisite, or comparative explanations.

Brusilovsky (2001) produced a new taxonomy of adaptive presentation based on the expansion of his 1996 AH taxonomy incorporating the developments and changes of AH research over the years, as follows:

- *Adaptive text presentation*, that is, adaptation of textual presentation which he further refined by dividing it into: canned text adaptation (inserting/removing fragments, stretchtext, altering fragments, sorting fragments, and dimming fragments) and natural language adaptation.
- *Adaptive multimedia presentation*, that is, adaptation of multimedia items.
- *Adaptation of modality* concerning adaptation of different types of media to represent the same data objects in a semantic way.

Nevertheless, most applications that employ adaptive content techniques are centred on the use of canned text adaptation, particularly '*conditional fragments*'. De Bra and Calvi (1998a, 1998b) used the term conditional fragment to specify that pieces of content will only be included or hidden in presentation when a definite condition is reached. There are different versions of the same page and they can be fragments of text or page, hence called *fragment variants* and *page variants* (De Bra and Calvi, 1998a, 1998b). Stretchtext is also a form of conditional fragment where the user can turn on and off pieces of content (Brusilovsky, 1996; De Bra and Calvi, 1998a). In addition, to facilitate content adaptation, *concept relationships* – a representation of associative formation of units of knowledge that make up a domain of the presented subject field – need to be structured but not necessary hierarchically (Bailey, 2001), in order to enable the author to make decisions on which piece of information will be rendered to users. Bailey (2001) claimed this technique requires a great deal of understanding of domain knowledge.

2.4.2 Adaptive Navigation Support

The goal of adaptive navigation support is to assist the user in navigation by means of changing the *appearance* (colour, font and style), *order* (a list of sorted links) and *quantity* of links presented. As its name, this method is more about providing users with more navigational strategies and guiding users to find the optimal path to follow in their navigation, hence requiring less knowledge about domains, than the adaptive presentation technique (Bailey, 2001).

Brusilovsky (2001) overviewed a new taxonomy for adaptive navigation support, as follows:

- *Direct guidance* highlighting the links to the next best node for the user to visit according to the user model, or present an additional dynamic link which is connected to the best node
- *Adaptive link sorting* sorting all the links in a particular page that appear to a user based on sorting algorithms
- *Adaptive link hiding* limiting the navigation space by hiding links leading to irrelevant pages or pages which are not ready to be viewed or visited by making the links appear as if they do not exist, but the links are actually still available
- *Adaptive link annotation* supplementing the links with some form of comment that gives the user more information about the current state of the nodes behind the annotated links
- *Adaptive link generation* discovering new useful links, generating links for similarity-based navigation, and recommending relevant links related to a page
- *Map adaptation* techniques for adapting the form of global and local hypermedia maps, as well as the structure of maps, presented to the user.

2.5 Review of Adaptive Hypermedia Systems and Applications

AH is concerned about the way in which information can be personalised and adapted. To date, AH researchers have presented a variety of systems and employed different strategies to facilitate this adaptivity. There was a discussion about the generalisation of the components within AH systems; however, there has been no firm consensus about the components such a universal system should comprise. This section gives an overview of some of the well-established AH applications and systems.

2.5.1 ISIS-Tutor

ISIS-Tutor (Brusilovsky and Pesin, 1994) is one of the earliest AH systems using link hiding and annotation. Different colours and marks are used to annotate the set of links and their associated items in accordance with the user’s current knowledge and goals. The system requires a basic user model.

2.5.2 INTERBOOK

INTERBOOK (Brusilovsky and Eklund, 1998) is a system for authoring and delivering electronic textbooks based on the World Wide Web that employs server-side technology with the use of multiple windows and frames. The system uses concepts which relate to each other by *if-then* relationships to represent knowledge presenting on a page that the user can learn. Once the user understands the first concept, they can then proceed to the second concept. The system applies adaptive navigation support by using different fonts and colours in order to indicate the status of a link: 'ready-to-be-learned', 'not-ready-to-be-learned', 'visited', and 'unknown'. These states are changed when the user's knowledge increases. In addition, the system also provides a glossary, which has links to and from the main page.

2.5.3 ELM-ART

ELM-ART (Brusilovsky *et al.*, 1996) is an adaptive learning system which was developed to teach introductory LISP on the WWW. It is an electronic textbook providing learners with interactive features such as tests, quizzes, programming support, interaction with tutors and other peers via a chat room, and with adaptive presentation and adaptive navigation by means of link annotation and link sorting. User models (one model allows for link annotation, and another model enables the system to analyse and individualise programming problem solutions) are dynamically updated during the session, and used as a means for adaptation. All documents presented to users are generated dynamically while the system is running.

2.5.4 AHA!

AHA! (Adaptive Hypermedia Architecture) (De Bra and Calvi, 1998a) is a generic adaptive hypermedia system that provides a platform for many areas of hypermedia application including educational ones. The AHA! architecture comprises the domain model (how concepts or pages are related to each other), adaptation model (rules that are used to update the user model based on the requested page and used to adapt the presentation of the page to the user), and user model (user information, preference, and how users relate to the domain model) (De Bra and Stash, 2002).

AHA! consists of concepts which are used to represent the subject domain. A concept can be a fragment, page, or object and has interconnection with other concepts through “concept relationships” (De Bra and Calvi, 1998a). Each concept is associated with attributes, such as the *access attribute* (a Boolean attribute which becomes true when a page is accessed) and the *knowledge attribute* (an attribute that can be set to be increased or decreased once a page is visited and can have effect on the knowledge attribute of associated concepts). An attribute in turn consists of *conditions* and *actions*. The condition is expressed as a Boolean expression and can trigger the action which in turn consists of one or more assignments to update some attributes of other related concepts.

The AHA! system assumes that the user gains the knowledge by accessing (reading) pages, and the system uses this assumption to generate adaptation. The following steps (modified from De Bra and Stash, 2002) exhibit how the AHA! system operates once a user visits a page.

- The requested page is retrieved from the local file system.
- The domain model and the user model are loaded.
- The name of the page (which represents a concept) is passed to the adaptation engine.
- The adaptation model is executed and functions by activating the access attribute of that concept. The condition of the access attribute is checked, and if it is true then a number of related assignments of the attribute’s action will be triggered.
- The knowledge attribute is increased or decreased and may correspond to the knowledge attribute of other concepts depending on the concept relationships and requirement expressions.
- The user model is updated.
- The requested page is adapted by means of conditional inclusion of fragments, link annotation and link hiding.

In terms of adaptation, AHA! implements both adaptive presentation and adaptive navigation support. First, the contents of the page are adapted by means of conditional inclusion of fragments, or fragment variants, using the <if> tag followed by <block>. If the expression is true, the designated fragment is displayed, otherwise another portion is activated. This can be exemplified by the following code, which reads: if the beginner knowledge equals 100, then the message is displayed that the user is in intermediate level, otherwise the user is in the beginner level. That is, if the beginner knowledge is assigned to 100, it means that the user has already visited, hence learned, some of the introductory and beginner's lessons, and the user is then now ready for the next higher level (i.e. the intermediate level). The <if> and <block> statement can be nested.

```
<if expr="cThaiDutch_Beginner_knowledge==100">
<block>
    Intermediated Level
</block>
<block>
    Beginner Level
</block>
</if>
```

Secondly, the link adaptation can be seen by means of link annotation and link hiding. This is achieved by marking each link anchor as conditional. Once the requirement expression (the suitability of link destinations designed by the author) is met, the link will become good (ready to be visited links), bad (not-ready-to-be visited link) or neutral (visited link). The default colours are blue for good links, black for bad links, and purple for neutral links. However, the user can always tailor the colour of the link anchors to their own preference; hence enabling the link hiding technique when the colour of the links match the surrounding document text.

The later versions of the AHA! application, version 2.0+ has placed emphasis on the authoring tool aiding the author in constructing graphically the concept relationships required in the domain (De Bra *et al.*, 2003). For detail of the development of AHA! and its newer versions can be found on the Web site aha.win.tue.nl.

2.5.5 HERA

Hera (Houben, 2000; Houben, 2005) is an adaptive Web-based information system. The aim of the Hera research project is to develop software that generates automatic hypermedia presentations for semi-structured data that are retrieved from a heterogenoeous and dynamic set of information resources. The hypermedia presentations are delivered to a heterogeneous group of users with different preferences using different platforms to view the presentations.

2.5.6 JointZone

JointZone (Ng *et al*., 2002a; Ng *et al*., 2002b; Ng, 2003; Maier *et al.*, 2005) is a Web-based learning application, which was funded by the Arthritis Research Campaign. The goal of the application is to serve undergraduate medical students and practising doctors in the study of rheumatology by providing users with a rich source of self-exploratory learning materials, and reducing ‘cognitive overload’. Although there are many projects carried out in the AH field which assume that a page was read when users load that page without considering the time spent at each page and the pages visited by each user are stored in the user model, there are only few projects, e.g. MANIC (Stern and Woolf, 2000) and JointZone, which take into consideration the determination of whether a page is actually read. MANIC considers time spent. JointZone takes account of reading speed, power of assimilation and prior knowledge (Ng *et al*., 2001). In the JointZone project, information can be adapted to users according to their *knowledge level* which is evaluated by means of a prior knowledge test, or a self-selection level based on user’s registration; *their browsing history*, which is a record stored to keep track of pages that each user visits, and how much time each user spends on those page; and *their goals* which will lead users to pages based on selected learning goals.

2.5.7 HA^{3}L

HA^{3}L (Hypermedia Adaptation using Agents and Auld Linky) (Bailey, 2002) is a server-side, agent-based, AH application based on his initial work on PAADS and the later integration of agent-based framework with link service technology, Agent-Based framework for Adaptive Hypermedia (ABAH). The novelty of the ABAH is the representation of the first use of an agent-based framework to build AH applications, as well as representing general all-purpose framework for AH. HA^{3}L was built around the medical domain provided by JointZone (Ng *et al*., 2002), and used an agent-based link service to provide adaptive functionality. HA^{3}L’s system architecture comprises three agents expressed in the ABAH – *user model* (maintaining a record of all the user’s interactions with the system), *interface* (facilitating communication between agents and the user), and *adaptation agent* (communicating between the agents environment and the link server) – and the Auld Linky link server (serving the data objects and constructing adaptive functionality). Auld Linky will be further explained in Chapter 3.

2.5.8 ILASH

ILASH (Incorporating Learning Strategies in Hypermedia) system (Bajraktarevic, 2003) is a Web-based system with the novel idea of incorporating learning strategies within adaptive hypermedia. Its adaptation centres on the provision of an appropriate learning strategy for students whilst learning.

2.5.9 User-Controlled Link Adaptation

Tsandilas and schraefel (2003) proposed a novel approach of incorporating the direct manipulation technique with adaptive link annotation methods to provide an adaptable hypermedia system. The user is supplied with multiple topics of interest that the user can choose, and the system then manipulates how these topics and their associated links are presented or annotated to the user in a resulting page.

2.6 Summary of AH systems and applications

AH research has taken users' differences in background, tasks, and interests into consideration and provides an enhanced usability of hypertext functionality in terms of adaptation and personalisation based on this individualisation. AH allows same or different information to be presented in a number of dissimilar ways. Most early established AH systems and applications were centred on the employment of AH techniques for either adaptive presentation, or adaptive navigational support, or both, and mainly developed specifically in a particular domain. Table 2-1 provides a summary of techniques used in some of AH systems and applications, as described earlier.

Despite the fact that AH techniques offer users with personalisation of contents and links and their challenges, some of the criticisms of adaptive systems are that users are prevented from having control of the system's actions (Tsandilas and schraefel, 2004). That is the users do not always understand or find it difficult to understand what and why the system is adapting the contents and links. This is due to the fact as Millard *et al.* (2003) described that even though adaptation takes place dynamically based on users' current progress at run time, the adaptation is deterministically defined at design time and authors control and understand navigational paths available to their users. The users are not aware of the system’s behaviour and have no control over the system’s action, and hence they do not know the adaptation consequences. In addition, as seen in Table 2-1, exemplified AH systems and applications are centred on either adaptive presentation, or adaptive navigation support, or both. However, few systems have taken user’s choice into consideration.

Espinoza and Höök (1995) also suggested that users should have some control over the adaptivity but should not have to control it constantly. As a consequence, one of the primary objectives of this work is to propose a concept which allows users’ more control over personalisation. However, the issues such as the balancing control made available to users and the extent to which user should be made aware of system made changes, or the transparency of the adaptivity, can introduce other arguments (Conlan, 2003), which is beyond the scope of this work.

Systems	Adaptive Presentation	Adaptive Navigation Support	Learning Styles	User's Choice
AHA! (De Bra and Calvi, 1998a; De Bra *et al.*, 2003	Content fragment variants	Link hiding Link removing Link disabling Link annotation		
ELM-ART (Brusilovsky *et al.*, 1996)		Adaptive annotation		
ISIS-Tutor (Brusilovsky and Pesin, 1994)		Link hiding Link annotation		
ILASH (Bajraktarevic, 2003)	Conditional fragment	Link hiding Link annotation Link ordering	Learning strategy representation	
Interbook (Brusilovsky and Eklund, 1998)		Direct guidance Adaptive link annotation		
JointZone (Ng, 2003)	Conditional fragment	Knowledge-based link hiding History-based link annotation		
User-controlled adaptation (Tsandilas and schraefel, 2003)		Link annotation		Choice of topics of interest

Table 2-1: Examples of techniques used in AH systems and applications

2.7 AH Research Direction

AH researchers have expanded their research boundary from domain specific applications, employing particular AH techniques, to relate to issues such as shareability and reusability, and the Semantic Web. This section gives a brief overview of the research direction AH researchers have taken over the past few years.

2.7.1 Adaptive Web Systems

From AH systems, the term Adaptive Web has emerged (Brusilovsky and Maybury, 2002). In this paper, they noted that, like pioneering AH research that embraced pre-Web systems, the adaptive Web research has combined a number of different research approaches such as hypertext, user modelling, machine learning, information retrieval, and so on, to develop Web systems that are capable of adapting their behaviour in accordance with the background, goal or interest of individual users or groups of users. In this regard, they pointed out that the main difference was that the scope of AH has been widened to incorporate the technologies such as *adaptive content selection* and *adaptive recommendation* (the ability of the system to choose and rank most relevant items, and make recommendations based on individuals or groups of users with similar interests, respectively), as well as *mobile generation* (adaptation based on an expansion of the user model to respond to the context of a user's work such as location, time, computer platform and bandwidth (Brusilovsky and Maybury, 2002; Cheverst *et al.*, 2002).

2.7.2 Ontologies in AH

An ontology is defined as "*a specification of a conceptualisation*" or "*a specification of a representational vocabulary for a shared domain knowledge*" (Gruber, 1993a). Ontologies originated in the field of Artificial Intelligence, particularly knowledge engineering, to facilitate the shareability and reusability of knowledge (Gruber, 1993b). An ontology can be used to represent the relationships or semantics of data to support the information retrieval process. Ontologies and their technologies are research issues in their own right; therefore, this section and Section 2.7.3 give a concise overview of the use of ontology and its relation to AH research.

The use of ontology in AH is to provide a model for the shared conceptual representation of a domain concept. Together with Web Services and Semantic Web technology, the ontology provides an essential part of the system that makes possible the reusability of the data structure and its content between different components or applications.

2.7.3 Web Services and Semantic Web

Web services are software systems designed to support interoperable machine-to-machine interaction over a distributed network. The Semantic Web research has its primary objective as defining and organising data and its associated relationships in a way its meaning can be understood by software processes rather than people (Berners-Lee *et al.*, 2001). The two technologies are therefore commonly counterparts. While the Semantic Web represents semantically-defined data structures which can be interpreted by the machine, the Web services provide standard means to enable the interoperability between various applications that operate on heterogeneous resources or frameworks (Maneewattana *et al.*, 2005). Examples of Web Services and Semantic Web-based AH Systems are summarised below.

De Bra *et al.* (2004) proposed a new, modular AH architecture which allows the collaboration between different applications in the creation and maintenance of a user model. These different components communicate with each other via service invocations. Ontologies define the unifying system's terminology and properties of each system service, and promote the shareability and interoperability among the services. Similarly, Kuruc (2005) suggested sharing a user model between AH applications via the use of Web Service technology. These AH systems have their own domain and adaptation model and make use of User Model Web Service (UMWS) to manipulate their user model.

Aroyo *et al.* (2004) presented a service-oriented framework for adaptive Web-based systems based on the provision of richer semantics for the adaptive support, the standardisation of user profiling to facilitate adaptation, and the application of reasoning services within distributed Web applications.

In addition, Henze (2005) offered a modular framework for the development and maintenance of the personalised functionalities on the Semantic Web. The Personal Reader framework is a service-based architecture which provides the user interface, mediates between user requests and available personalisation services, and delivers additional personal recommendations on the viewing context.

Furthermore, Maneewatthana *et al*. (2005) presented a system called Adaptive Personal Information Environment (a-PIE), a service-oriented framework using Open Hypermedia and Semantic Web technologies to support the shareability and reusability of knowledge in response to the requirements of the users. a-PIE offers users the functionality to search an information space and add and/or manipulate required data into their personal information space without any changes in original information structures.

2.7.4 Remarks on AH Research Direction

AH research has recently been very much about the authoring of adaptable and adaptive hypermedia, applying service-oriented architectures to adaptive Web-based systems, recommender systems and intelligent user interfaces, and the application of the Semantic Web Technologies for adaptive hypermedia and adaptive educational hypermedia. Since 2003, there have been no major steps in establishing new methods for the adaptation of *contents* and *links*. Adaptive Web-based systems are no longer single or domain specific applications, but instead modular distributed applications, where new technologies have been implemented so that user models and adaptation rules can be shared and reused amongst multiple distributed applications (De Bra *et al.*, 2004).

Semantic Web technologies can support AH by enhancing existing adaptive techniques and providing an alternative view for adaptation. Ontologies can be applied to describe the system's terminology and properties of the system for sharing and interoperability among the service-oriented systems. Ontologies can enhance the adaptation of contents by providing richer formal descriptions of content authoring and facilitating the sharing of meanings and semantics of information (or knowledge) between different modular systems (De Bra *et al.*, 2004). As for the AH's adaptive navigational support technique, ontologies can play a part in the links construction. Additional links can be dynamically inserted based on the open hypermedia concept, which will be described in Chapter 3, in relation to the chosen or suggested ontologies. Ontologies can be exploited to decide links, which would allow words in the hyperdocument to be linked based on the relationships between concepts in the ontologies. A semantically-derived AH system can suggest ontologies for navigation based on the user profile and the page content the user is navigating. This would enable the navigational links to be adapted based on different users or groups of users.

2.8 Summary

This chapter has given the background to the research in hypermedia and adaptive hypermedia. The history of hypertext evolved from the hypertext pioneers Vannevar Bush and the idea about his Memex system in 1945, Engelbart and his NLS in 1962, as well as his invention of the mouse pointing device, and Ted Nelson and the Xanadu project, who coined the term hypertext as a non-sequential way of reading and writing information. The concept of hypertext permits associations of textual information as well as images and media other than text to be linked non-sequentially in a variety of ways, which results in the capability of following these associations and searching for related materials easily and quickly. However, due to the fact that it provides users with free exploration, it can generate usability problems such as *cognitive overhead* and *disorientation.* This is how the adaptive hypermedia community has begun.

AH research is aimed at providing the functionality to solve the problems caused by traditional hypermedia systems and also increase their functionality. Taking users with dissimilar interests and goals into consideration enables the users to be provided with relevant pieces of information corresponding to their individual user profile. The two main techniques comprise adaptation of the *contents* and *links* available in the information space. The user model which captures user information such as user registration, interest and background, is an essential component used to make personalisation possible. Despite AH enhancing how information to be adapted online, one of the criticisms of adaptive systems is that users find it difficult to understand and control the system's actions. One of the primary objectives of this work is therefore to address this issue and will be further elaborated in the following chapters.

The next chapter will continue to centre on another primary research area of the work documented in this thesis, namely open hypermedia. Like AH, open hypermedia also provides a great platform for personalisation and adaptation. However, it takes a different approach and philosophy which will be discussed in the next chapter.

Chapter 3 Open Hypermedia and FOHM

3.1 Introduction

In Chapter 2, the concept of hypermedia and adaptive hypermedia was presented. This chapter focuses on open hypermedia and its related issues that have influenced this thesis.

This chapter first documents Open Hypermedia (OH) research, its philosophies and concepts, as well as examples of OH systems. Secondly, the chapter explains the link service approach, or the link-oriented view of hypermedia, particularly the link augmentation technique which has been termed as the process of inserting supplementary links. Then, the chapter highlights the Fundamental Open Hypermedia Model (FOHM), a model of open hypermedia with contextual structures developed at Southampton University, and Auld Linky (formerly named Auld Leaky), a contextual link server designed to store and serve FOHM structures, which are the primary research areas that this work is built on as a means to implementing an AH system. Finally, this chapter gives a brief description of open adaptive hypermedia and ontological hypermedia research.

3.2 Open Hypermedia

One of the problems in early hypermedia systems is that most of them were closed systems. By closed systems, is meant systems that provide a fixed set of applications that are tightly integrated with the hypermedia linking mechanism, hence not allowing the data or links to be accessed from outside the hypermedia system (Davis *et al.*, 1993; Hall, 2000; Hothi, 2001). In addition, the fact that links are embedded into the structure of document, and that these documents need to be converted to a format supported by the system environment, leads to the authoring and maintainability problem (Goose, 1997). In contrast to this, the open hypermedia community proposed the idea that hypermedia systems should provide a protocol that allows applications to be loosely integrated with the hypermedia linking mechanisms to take part in the hypermedia service (Davis *et al*., 1993; Lowe and Hall, 1999; Hall, 2000).

3.2.1 Concepts of Open Hypermedia

The main idea of open hypermedia is the separation of links from documents and treating them as first class objects (Davis *et al*., 1993). In open hypermedia systems, links are stored in link databases (linkbases) instead of being embedded into documents. This enables the links to be stored, processed, retrieved, and applied to documents of any format (Carr *et al*., 1998). This link maintenance decreases the authoring time and managing effort, as documents do not need to be edited or amended every time the links are changed or edited (Carr *et al*., 1995). The provision of links this way, which researchers have termed *the link service approach*, allows client applications to manipulate (create, edit, and activate) links freely (Fountain *et al.*, 1990). In addition, the documents themselves can be accessed externally by other programs, hence promoting extensibility and interoperability (Bailey, 2002).

The criteria for truly open hypermedia systems include the following aspects (Davis *et al*., 1993; Hall *et al*., 1996; Lowe and Hall, 1999; Hothi, 2001):

- unlimited size of domain
- the use of any data format
- being accessible by any application
- the ability to import new contents, links, and anchors
- the possibility of implementing on distributed platforms
- supporting multiple users
- having no distinction between readers and authors
- and enabling users to hold individual views within the systems

It is noted that to date no systems can be said to be truly open (Hothi, 2001; Zhou, 2004).

3.2.2 Examples of Open Hypermedia Systems

OH research has covered various issues, from early attempts to construct hypermedia across different types of media (Intermedia), provision of link server functionality (Sun's Link Service), to creation of hypertext across hetrogenous environments (Chimera) and distributed open hypermedia (Hyper-G). This section describes some of the early OH systems.

Intermedia (Yankelovich *et al.*, 1988) was developed at Brown University's Institute for Research in Information and Scholarship (IRIS) and was one of the earliest systems which applied the concept of the link service. It was a multi-application hypermedia system which allowed users to author and follow links across its various applications. Links were preserved in the Intermedia environment and manipulated by a link server. Users could also require different sets of links (multiple links) on the same document and create and maintain their own set of links. Intermedia, however, contained a closed link service that could only be accessed within its own environment (Bailey, 2002).

Sun's link service (Pearl, 1991) was the first protocol for the link service integrated in addition to other components to provide linking functionality. The link service functioned as a central intermediary where other applications needed to register for their link handling capabilities. However, it offered access to only a single linkbase (Bailey, 2002).

Chimera (Anderson *et al.*, 1994) was a client-server open hypermedia system, aimed at the provision of hypertext services in heterogeneous software development environments. Its principle lies in the concepts of objects (or entities), viewers (entities that display objects), views (an association of a viewer and an object, where an object can sometimes be viewed by more than one viewer), anchors (visual components such as buttons managed by viewers with respect to the particular view of the object) and links (set of anchors used to relate to views).

Hyper-G (Andrews *et al.*, 1995) was described as a multi-user, multi-protocol, structured hypermedia information system. It was client-server based, where the Hyper-G server consisted of document server, full text server and link server. The link server in particular stored a database of objects and their relationship with other objects. These objects include documents, anchors, and their hierarchical structures (called collections).

3.3 The Link Service Approach

The link service approach, or the link-oriented view of hypermedia, originated from the open hypermedia community. It is not yet significantly present in the AH methods and techniques proposed by Brusilovsky (Brusilovsky, 2001); however, there has been subsequent work introducing the concept of OH to the field of AH that resulted in an additional technique, namely "link augmentation" (Bailey *et al.*, 2001). It was defined as *a technique whereby external links are inserted directly into the body of a document* (Bailey *et al.*, 2001). This differs from link annotation, one of the adaptive navigation support techniques, in that link augmentation is the process of dynamically inserting additional links into an existing Web document, whereas the link annotation process concerns more about the visible properties of links (Bailey *et al*., 2001). In fact, the process of inserting additional links into the body of a document is not a new technique but an existing OH technique. However, the technique had not yet been named properly until the work undertaken by Bailey *et al*. (2001). As a result, the link augmentation technique should have been fittingly added amongst other techniques of adaptive navigation support.

Within this approach, links are separated from the body of a hypermedia document and stored independently in a linkbase (link database). A linkbase can be viewed as a database of link structures. An example of a linkbase is a store of links in a single place (source and destination information) which are related in some way. Links can be related in many different ways, for example, the destination points can be documents relating to information about a topic such as 'volcano', the type of material being linked to, e.g. scientific papers, presentations or the quality of material being linked to, e.g. beginner guides or highly technical material. A link service or link server is required to then provide link functionality. It serves as an interface to one or more linkbases and provides a query interface to other applications.

Link servers function on demand, meaning that a client application incorporating with a link service can dynamically insert additional links from a variety of linkbases into a Web page that corresponds to the user profile. For instance, the linkbases can be established and categorised as the beginner linkbase and advanced linkbase. In doing this, each user will observe the links in accordance with his or her own interest, background, or level of expertise or knowledge. A beginner using an application being augmented with links from a 'beginner linkbase' would notice new links appearing that lead him or her to more descriptive information, or attain additional links; whereas an advanced user using an 'advanced linkbase' would be presented with attached links directing her or him to more advanced information, or perceive fewer supplementary links.

It is claimed that the main advantages of the link service approach are that links can be created, added, or modified without the original document being affected, and despite the text being modified or moved around, the links would still function (Hughes, 2000; Bailey *et al*., 2001). It has also been highlighted that this approach greatly reduces the information maintenance workload and increases the authoring capability (Carr *et al*., 1995).

At the University of Southampton, open hypermedia research commenced in the early 1990's. The link service was first developed as part of the Microcosm application. Microcosm (Fountain *et al*., 1990) was established to be an open hypermedia system where users were provided with dynamic, cross-application hyperlinks on the fly for use in education. Its aim was to reduce the authoring effort and allow the links to be applied to read-only media, such as CD-ROMs, or third party applications (Davis *et al*., 1993; Hall *et al*., 1996; Hall, 2000; Hothi, 2001). Despite not being widely categorised as an adaptive hypermedia application, Microcosm provided a framework for adaptive hypermedia. The essential feature in Microcosm was that the links were generated by the Microcosm mechanism rather than being embedded within the content. The Microcosm link service stored a set of linkbases and augmented the links maintained in these linkbases onto the user's exisiting application. The separation of links from the content enabled the reusability of the content (Hall *et al*., 1996), meaning that the same content can be reused to display to different users, which is a crucial requirement for an adaptive hypermedia system (Hothi, 2001). Another outstanding feature found in Microcosm is that it provides the user with the ability to create his or her own links within existing hypermedia documents without changing the basic structure constructed by the system author (Davis *et al*., 1993; Hothi, 2001). This aspect was implemented by allowing the user to highlight any text, and query the system for any associated links. This enables the adaptivity aspect.

After the appearance of the WWW, the Distributed Link Service (DLS) was developed to widen the Microcosm philosophy by supporting multiple users, operating in a distributed environment and incorporating the new Web model. It was an OH link service system providing hyperlinks on demand to other applications. In the first implementation of the DLS, users were provided with the functionality that enabled them to actively request the system to return a set of extra links using the interface menu. However, the problem with the first implementation was that it was platform and browser dependent. In the later development, the DLS has been implemented as a Web proxy. Once the proxy is in use, documents viewed in any browser are inserted with blue underlined words, and the user can simply click on them to follow links (Carr *et al*., 1995; Hall *et al*., 1996). Auld Linky (Michaelides *et al.*, 2001), formerly called Auld Leaky, is a contextual link server, the latest generation of the link service at Southampton. Auld Linky can be used to dynamically respond to users' requests for link matching, which will be again explained in Section 3.6.

There have been other existing systems which were developed to provide link augmentation. As previously described, Intermedia, Sun's Link Service, Microcosm and DLS were amongst other OH systems which employed the link augmentation technique. Another is WeB Intermediaries (WBI) (Maglio and Farrell, 2000), a proxy-based system that analyses every page a user visits and replaces any known word or phrase in a related page with hyperlinks from its knowledge base about the subject. If the user follows any of these links, the user will then be delivered with supplementary resources. A further OH system is the Personal WebWatcher (PWW) system (Mladenic, 1996), a server-side system that provides recommendations to pages in the website based on the URL and/or content of refereeing pages.

Despite its advantages, there are also many problems with link augmentation techniques. Bailey *et al*. (2001) noted that most existing applications base their link insertion on keywords or phrases in the source document. However, there is a problem in words that have different meanings in different contexts. This can seemingly cause too many irrelevant links or links appearing in the wrong context. In addition, there is also a problem when every chosen word becomes a link which results in too many links inserted into an existing hyperdocument.

At the University of Southampton, the first problem was solved by the novelty of applying context analysis as a method of filtering out irrelevant links, as applied in the QuIC project (El-Beltagy *et al*., 2001), a multi-agent system which was developed to assist users in navigation and information finding. The second problem with too many generic links or *prolific linking* was dealt with by 'ontological linking' as applied in the

COHSE project (Carr *et al.*, 2002). COHSE integrates the DLS with ontological services to provide linking based on concepts which exist in Web pages. However, COHSE was not proposed to be an AH system. Therefore, there were no adaptation techniques implemented, as well as no engagement of user profiles to support personalisation or adaptation of presented links. Another possible means to sift out irrelevant links is the use of the concept of a multi-dimensional linkbase. By this technique, we consider that users exist in different dimensions of expertise and hence should be presented with different sets of links from different expertise dimensions. Irrelevant links which are not of concern will be filtered out and only the corresponding links will be augmented and presented. This concept will be fully explained later in Chapter 5.

3.4 Open Hypermedia Protocols and FOHM

As in any engineering research, there have been attempts to generalise a standard protocol in order to allow communication and interoperability between different OH systems. The first standard protocol proposed was called the Open Hypermedia Protocol (OHP) (Davis *et al.*, 1996). It was a protocol which made possible the communication about hypertext objects, such as anchors, links nodes, etc., between client-side application programs and link servers. OHP-NAV protocol was the second development – a text-based protocol – developed to specifically underline the navigational domain (Millard, 2000). Further research at the University of Southampton produced the Fundamental Open Hypermedia Model (FOHM).

FOHM (Millard *et al.*, 2000) is a generalised model of hypermedia which encompasses several domains of hypertext, namely *navigational*, *spatial* and *taxonomic*. *Navigational hypertext* is the more common hypertext system which provides the user with navigation between documents or within a document by the use of links created by the author. *Spatial hypertext* facilitates the user in organising information into logical spaces, hence allowing them to traverse the hyperspaces themselves instead of the provision of standard navigational hypertext systems. The spatial hypertext systems also implement the use of visualisations, such as colour and size, to present information nodes according to their relationships with other existing nodes. *Taxonomic hypertext* systems concern the categorisation of information into hierarchies.

3.5 FOHM Structures

The FOHM is a model for open hypermedia with additional context-awareness features (Millard *et al.* 2000). It describes the structure of hypertext objects and their associations between data. There are four first-class objects, namely *Association*, *Data items*, *Reference*, and *Bindings* (Millard *et al*., 2000), as shown in Figure 3-1.

Associations are structures that represent relationships between Data objects.

Data items or objects are items of information which can be words, paragraphs, concepts or entire documents lying outside the scope of the model.

Bindings are attributes which specify the connection between Associations and Data items.

Reference objects are pointers to the entirety of Data items or parts of the Data items.

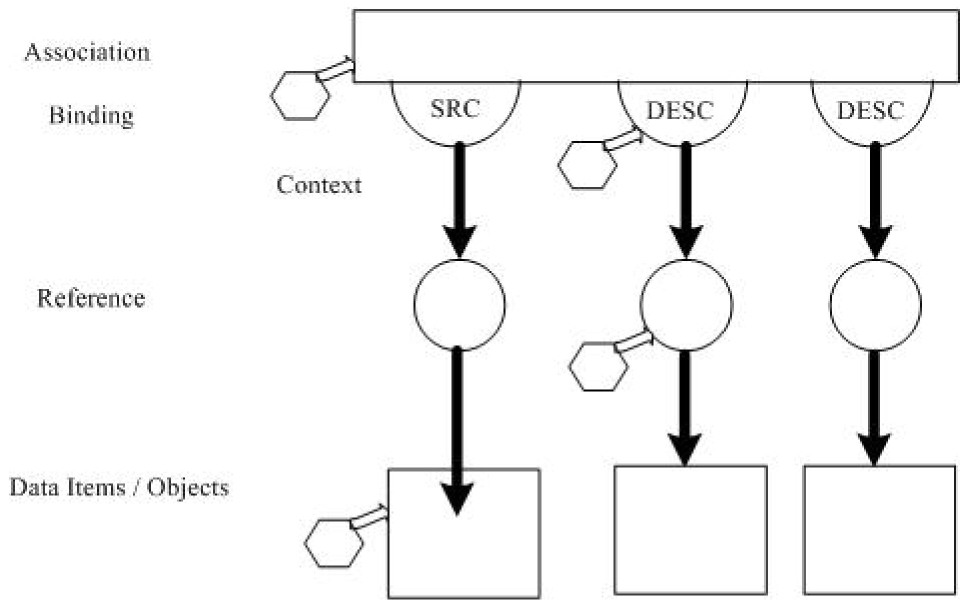


Figure 3-1: A basic FOHM structure with the Context object attached

(redrawn Millard *et al*., 2000)

Two other modifier objects exist in FOHM which can be attached to the various parts of the hypertext structure (associations, references, or data items); these are called *Context* and *Behaviour*. *Context* is used to define the conditions whether or not we want certain objects to be visible according to individual users. The context object is integral to the personalisation and adaptation mechanism. It is an attribute-value pair: *context* and *context value* which can be used to describe which part of the structure can be seen. For instance, we can use a context object to attach to a data item and indicate that we only want this data to be viewable if the user's context matches the context value 'beginner'. Like the Context objects, the *Behaviour* objects can also be attached to different parts of the FOHM structures. They are used to notify the client applications that handle the FOHM structures about certain actions to be performed at given event conditions such as *display* or *traversal*. For instance, the behaviour object can be attached to a data object and has an event type 'display' associated with it. The 'display' event specifies that the behaviour will be triggered or functional when the data object is displayed. Another example is to use the Behaviour object to update the user model when the user reaches a certain point in the structure.

In addition, the Context and Behaviour objects can be attached to any part of the hyperstructure and at serveral different points in a hyperstructure. This context attachment provides an adaptation (personalisation) mechanism by means of defining the conditions for the visibility of the structure. For instance, the structure can be a navigational link which has a context object attached to it indicating that this link structure is visible only to advanced users, whereas another link can be specifically noticeable and accessible only to and by beginner users. When the link structure is viewed the user's context from the user model (e.g. 'advanced') is compared with the context object and its context value ('advanced') using the matching function provided by the link server, part of the structure that fails the matching process will be removed from the view and only the remaining structure will be returned to the user. This provides an effective platform which can be used to implement AH systems.

FOHM uses all these fundamental first-class objects (components) available to model complex and diverse hypermedia structures: *Navigational Link*, *Tour*, *Level of Detail*, and *Concept*.

Navigational Link: an association that is assigned to be the navigational link type, with a source binding, and one or more destination bindings, pointing to a region within a data item or to a complete data item(s). This OH structure is the fundamental and only structure used throughout this thesis.

Tour: an association that represents an ordered set of objects that can be data items, other associations, or a combination of both.

Level of Detail: an association that signifies an ordered sequence of objects. Each object models the same conceptual information with the increase in the detail and complexity. For instance, the first item of the presenting concept can be a summary, then the second item can be a greater explanation.

Concept: an association that is a collection of objects representing the same conceptual information but with different representations of media types.

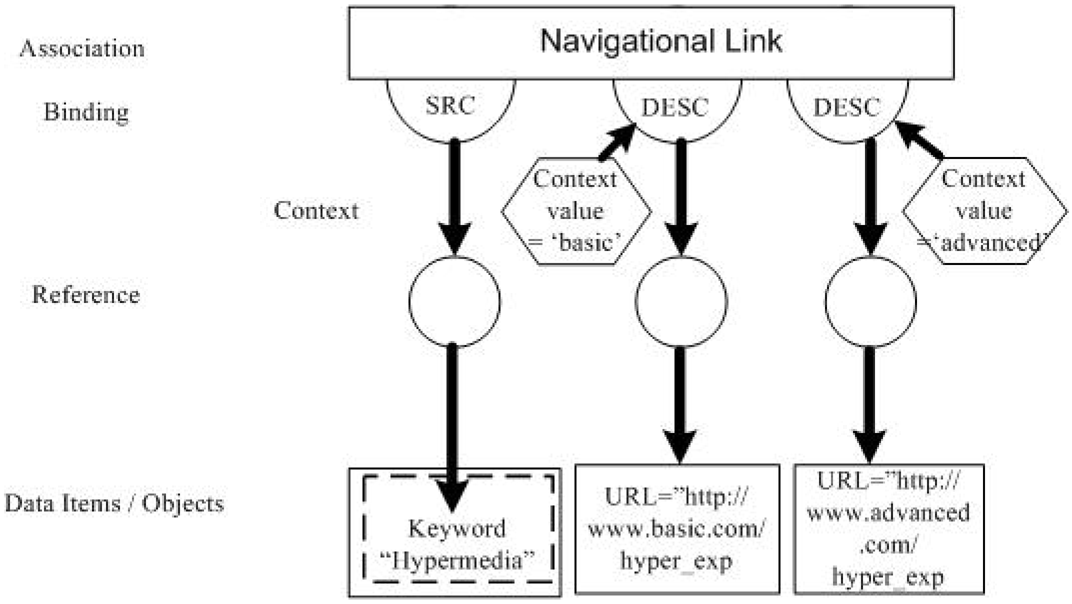


Figure 3-2: A FOHM Navigational Link Structure

Figure 3-2 examplifies a navigational link that contains a single source (SRC) anchor, and two destination (DEST) data objects. The source location references a particular region in the data object such as keyword, phrase, or paragraph, which in this example is the location with the keyword "hypermedia". The two destinations explain the keyword "hypermedia" (with two urls), the first one with the 'basic' detail and the second one with the 'advanced' detail. Context objects ('Preference') are attached to the two destination bindings, meaning that while the link (the source, "hypernedia") will always be noticeable, the destination will provide the explanation dependent on the user model.

3.6 Auld Linky

Auld Linky (Michaelides *et al.*, 2001), formerly Auld Leaky, is a stand-alone program that was developed to serve FOHM structures. It is the latest generation of the link service, developed as part of the Equator project in the IAM group. It is a contextual OH link server which stores FOHM structures as XML objects and offers a query mechanism to serve this structure to client applications. Client applications can query Auld Linky sending a FOHM structure as well as associated context. The link server then performs the link matching process to compare the query structure with the FOHM structure stored internally in its linkbase(s) and generates the matches. Next, any parts of the query structure which do not match the resulting structure will be removed from the results, *context culling process*. The result from the culling process will then be returned to the clients.

To clarify this, let's consider Figure 3-2 again. When a user queries Auld Linky by sending a FOHM structure and an associated context 'Preference' as 'advanced', Auld Linky will compare the query structure with the structure stored in the linkbase, generate the matches, and then perform the context culling process. Auld Linky will then remove the inappropriate destination and only the destination with the context value 'advanced' will be visible to the user.

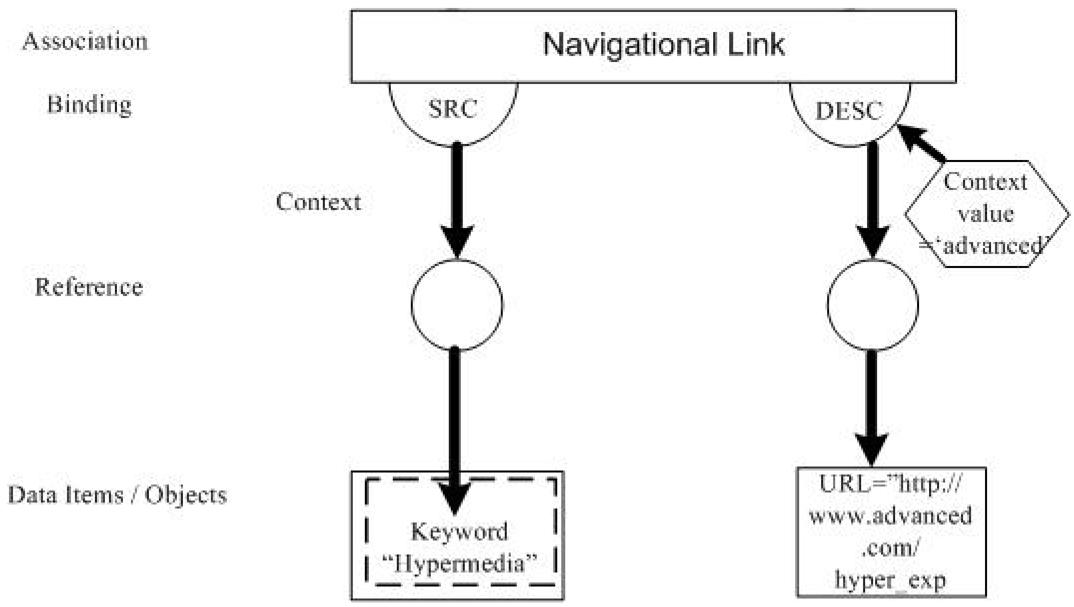


Figure 3-3: Remaining FOHM Link Structure after the context culling process

3.7 Open Adaptive Hypermedia

There has been subsequent work introducing the concept of open hypermedia to the field of adaptive hypermedia. On the one hand, AH is claimed to be more concerned about the way in which information can be personalised and adapted at content-, or link-level, based on a user's profile, than the link structure and system architecture (Millard *et al*., 2003). Millard *et al*. (2003) noted that AH research took a deterministic approach to the design of hypertext systems. By this terminology, they intended that although the adaptation process dynamically occurs based on a user's current status at run time, it is predefined at design time. The designer oversees the navigational path the user would have to follow. On the other hand, they noted that the OH technique provides a free-form approach which can be used for adaptation. The separation of links and the document enables additional hyperstructure or links from a linkbase (or multiple linkbases) to be augmented into the hyperspace at run time. This enables existing Web pages to be personalised with additional links based on the user's selection. Within this approach, it is believed that the user might find it easier to understand the adaptation process rather than typically complex adaptive systems, where the user has no way to comprehend what is happening behind the scenes.

Other reseach has also used the term 'Open Adaptive Hypermedia'. Henze (2001) noted that an open adaptive hypermedia system is one that operates on an open corpus of documents. By an open corpus, she suggested that the system should be able to integrate other online materials available in the Internet with existing AH systems which is done by the separation of hypermedia system and adaptation components. An ontology is employed as a knowledge model to describe concepts that in turn define a controlled vocabulary for the application domain and that are used for making the metadata annotation of the document space.

Another research attempt to bring the concept of OH, particularly the architecture and link models of OH, to the field of AH include the work undertaken at the University of Southampton. FOHM and Auld Linky, as previously described, have been used as a means to implement AH systems (Bailey *et al*., 2001; Bailey, 2002; Abdullah *et al*., 2004, Maneewatthana *et al.*, 2005). FOHM makes possible adaptation in its context mechanism that determines the conditions of the visibility of the structures. Auld Linky performs the culling process and returns only the structure matching the stated conditions.

Bailey *et al*. (2002) applied FOHM contextual structures to explain and clarify Brusilovsky's adaptation taxonomy. It was concluded that although the structural OH approach was unable to totally support the taxonomy of AH techniques, and may not have provided the best programming solution, it did inform the AH community about the consistency and the advantages the approach could provide. In addition, with modification to FOHM and Auld Linky, most of the techniques identified by Brusilovsky could then be supported.

Furthermore, Abdullah and Davis (2005) proposed a real-time personalisation service for SCORM using FOHM and Auld Linky to supply learners with dynamic personalised links based on the users' preferred learning style. The system uses the concept name and the user's preferred learning style obtained from a user model to query the link server and the link server will return supplementary links at run time according to the given concept name and the user's preferred learning style.

3.8 Ontological Hypermedia

An ontological hypertext is an ontology-based hypertext. An ontology defines the semantic relationships between objects in the real world or a specific domain. An ontologically-based hypertext system structures or links together a network of these components. Ontology-based linking, or ontological linking, offers a common understanding of domain knowledge or concepts and of what is to be linked and can be linked (Woukeu *et al*., 2003). Ontological linking is dissimilar to taxonomical linking in that the former incorporates the semantic relationships of a topic or concept in that particular domain rather than lexical linking of individual word or phrase. Figure 3-4 illustrates a representation of the ontological linking.

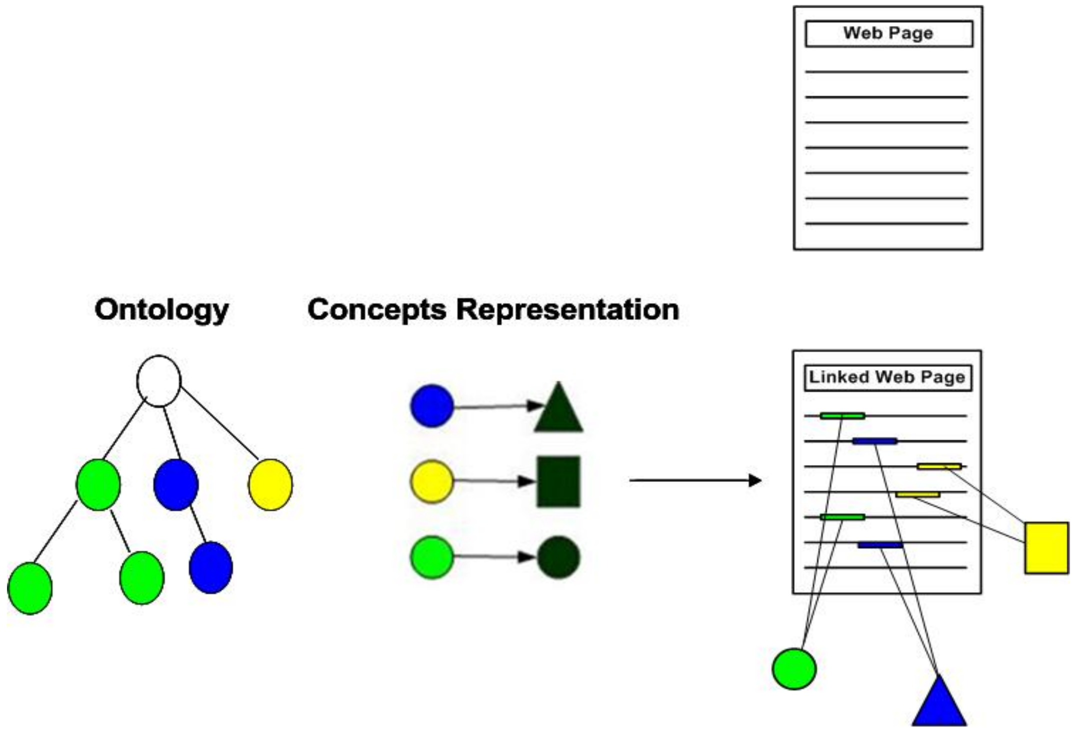


Figure 3-4: Ontological linking (modified Wills, 2005b)

As can be seen in Figure 3-4, an ontology represents the semantic relationships between data objects (◯). A concept (e.g. △) is a collection of atomic data items or objects. A same colour is used to represent same concept. Rather than base linking on words or phrases, ontological linking centres its linking mechanism upon concepts which are interconnected with other concepts by means of sematic relationship types. This results in a hypertext that has structure and links derived from the relationships between objects in the ontology. The ontological linking offers an advantage over simple lexical matching in that the latter has no means of controlling the method of adding generic links (Wills, 2005b). Within this regard, the ontology linking is claimed to assist the information searching process more semantically and precisely (Maneewattana *et al.*, 2005).

Example of the application of ontological linking includes COHSE (Conceptual OHS Environment)(Carr *et al.*, 2002). The COHSE project is an ontological hypermedia system, which integrates an open hypermedia link service with an ontological reasoning service. It presents the linking based on the concepts that appear in Web pages. COHSE allows the documents to be annotated based on description logic provided by the reasoning service and performs the documents' annotation at browsing time (Carr *et al*., 2001).

3.9 Summary

This chapter has given a background of fundamental research to the Open Hypermedia work underpinning this thesis. The open hypermedia (OH) community emerged and its underlying principle centred on the separation of the links from documents. This possesses a number of advantages, such as reducing authoring and maintenance effort and allowing new functionality to be added easily. Link augmentation is a technique under this discipline. It was defined as a technique whereby external links are inserted directly into the body of a document. In addition, the OH research at Southampton University produced the Fundamental Open Hypermedia Model (FOHM), and to serve the idea behind it, Auld Linky, the contextual link server was also developed.

FOHM and Auld Linky have been used to implement several AH systems. FOHM encodes adaptation rules in the context mechanism. The context object conditions the visibility of the hyperstructure. Auld Linky is a contextual link service created to serve FOHM structure. Collectively, the two can be used to dynamically respond to users' requests for link matching which results in links personalisation.

Open Adaptive Hypermedia research has been undertaken to look at combining features of both AH and OH. Millard *et al*. (2003) described that, unlike AH where the possibility of contents and links adaptation is predefined by the system's author at design time even though adaptation dynamically occurs at run time based on user's current progress, OH research has taken different approaches to offering free-form adaptation. By using a non-deterministic approach, they noted that the separation of contents and link structures permits the additional hyperstructure, such as navigational links, to be inserted at run time.

Ontological linking provides semantically derived hypertext. It allows agreed and shared representation of knowledge in heterogeneous environment and provides linking based on the concepts as existing in Web pages.

The next chapter will document the initial work and early investigations which provided the grounding knowledge for the work documented in this thesis.

Chapter 4 Initial Work

4.1 Introduction

This chapter presents the result of the initial experimentation in the area of open adaptive hypermedia. The objective of conducting these experiments was to provide another practical demonstration that the Link Service approach, particularly the process of link augmentation as previously explained in Chapter 3, could be used as an effective means for making Web-based personalised navigation systems.

Traditionally, OH can be used to support adaptation by means of supplementary contents and navigational links, particularly generic links. A *generic link* is a navigational link of a particular object at *any* position in a source document that associates with a particular object in a destination document (Davis *et al.*, 1993). These addditional links can be stored externally in a linkbase or multiple linkbases and are inserted into a Web page by means of the link server.

The three experiments were conducted with distinct purposes in mind, although their main function was centred on the link augmentation process. The objective of the first experiment was to implement the concept of link augmentation to a selected domain. Following this, the aim of the second experiment was to examine the possibility of integrating the link service with an established AH system like AHA!. The goal of the third experiment was centred on linking based on the concept of different dimensions in linkbases which essentially provided the grounding concept for the main scheme in the next chapter. This chapter concludes with the proposal to resolve the link overload problem by the application of the concept of a multi-dimensional linkbase, which is the core of the thesis and will be fully elaborated in Chapter 5.

4.2 Technologies

There are two main technologies used to implement all initial experimentation and are essentially the core of the thesis – *Proxy* and *FOHM / Auld Linky*.

First of all, a proxy is a device that acts as intermediary between the Internet and an individual browser. It functions between the browser and the server. When a client requests a page, the request is forwarded to the proxy. The proxy, on behalf of the browser, requests the page from a server. At this point the proxy can then modify the requested document before finally forwarding the page to the user's browser. All experiments conducted for this thesis made use of an in-house Java Proxy which was later specifically modified to perform link augmentation and link presentation.

Secondly, FOHM and Auld Linky, as described in Chapter 3, were used to implement an adaptation mechanism. Auld Linky is a context-based link server that stores and serves structures expressed in FOHM. It is a program, written in Perl, which communicates via XML-formatted messages over HTTP, stores queries in a linkbase, provides the query process via pattern matching, and produces the results by removing the part of the structure that fails to match the context value in FOHM and sends the remaining structures that match the user's requests to the applications (Michaelides *et al*., 2001).

4.3 Link Augmentation with Auld Linky

This first experiment was designed to provide the author with the practical experience on how the links could be augmented into a page. An educational Web site teaching cookery skills was constructed to serve as a platform for distributing the online information and also as a simple adaptive system. The cookery domain was chosen as it was relatively simple and straightforward to insert additional links which were aimed to give additional explanation, and the links could be rendered to different users based on their stereotype, beginner or advanced. Most existing Web-based adaptive hypermedia systems were created to teach universal subjects such as mathematics, medicine, computer science and so on, so this was chosen to provide an alternative, and it is also the subject known to the author.

The Web site comprised the domain model (topics concerned with cookery) and the user model (a database that stores information about an individual user, that is, name, surname, password, and user categorisation, as previously described in Section 2.3.2. The user is recommended to complete thirty multiple-choice questions, and the pre-test score identifies the user categorisation. The UK standard assessment criteria was chosen to categorise users based on their pre-test score, i.e. a threshold value of 70% was employed. If the user scores below 70%, then the user is categorised as a beginner. Otherwise the user is regarded as an advanced learner. The user can then move on to study the presented materials. Straightforward adaptation techniques were applied. Firstly, adaptive presentation was employed by means of conditional inclusion of fragments using 'if-else' statements which enabled decisions made on what links or content is to be displayed to the user based on the user's pre-test result (i.e. beginner or advanced). For instance, the code shown in Figure 4-1, a very AHA-like approach using ASP, illustrates the idea of how the conditional fragments are implemented.

```
<% // to check if the user has already taken the test %>
<% // if users have not yet taken the test then the following code is activated %>
<% If isEmpty(percentile) Then %>
        <% // display one thing %>
<% // if users have already taken the pre-test and scored > 70%, the following statement is valid %>
<% elseif percentile > 70 %>
        <% // display another thing %>
<% // if the user has already taken the test but scored < 70%, then this statement is valid %>
<% else %>
        <% // display something else %>
<% end if %>
```

Figure 4-1: The use of conditional inclusion of fragments in ASP

Secondly, adaptive navigation support was put into practice by the use of adaptive link hiding (i.e. making the links appear like the surrounding text but still active) and what is termed 'link augmentation'. As described in Section 3.3, the notion of the link service approach is that links are stored in separate linkbases and the link server enables the links to be augmented into the content page as they are viewed through the browser by the means of a proxy server.

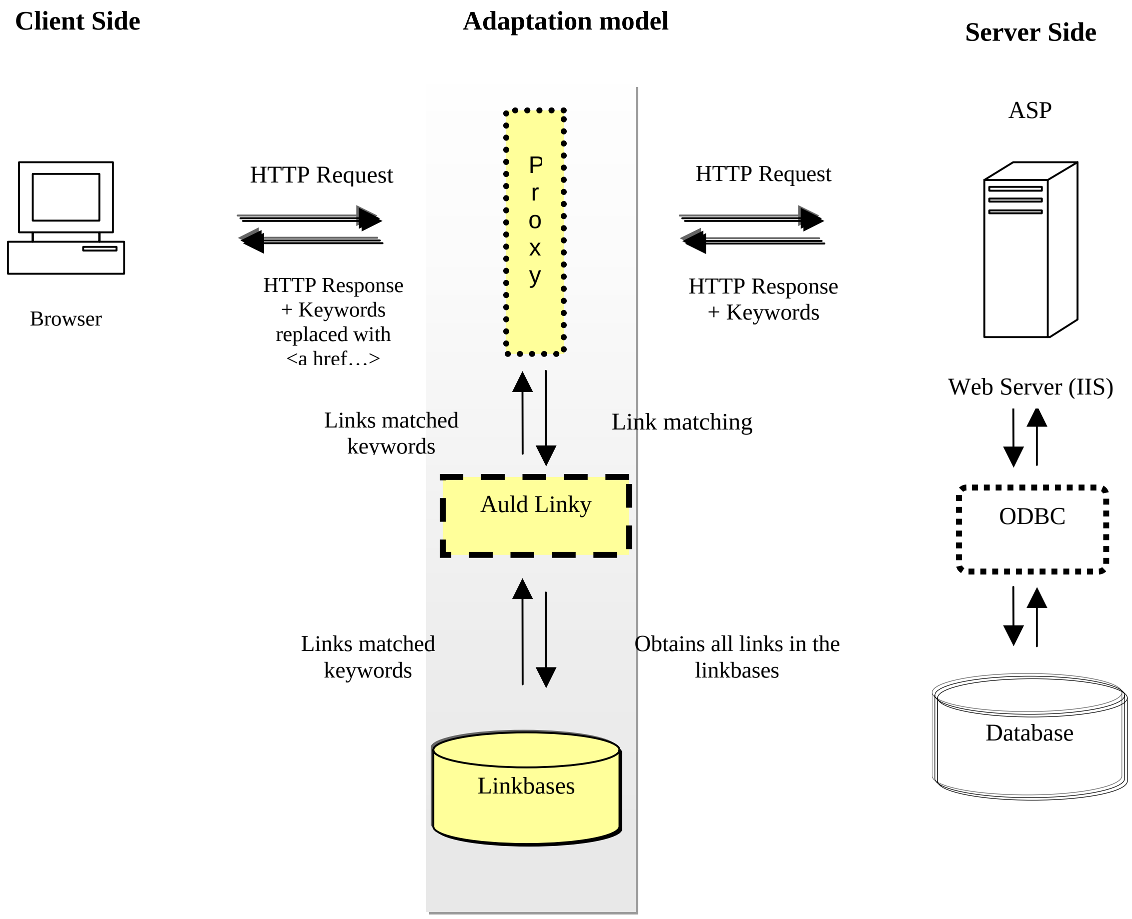


Figure 4-2: The system architecture of the cookery website

Figure 4-2 describes the system architecture and how the system functions. First, a client requests a Web page embedded with ASP scripts. The request is then sent to the proxy and passed on to the Web Server – the Internet Information Server (IIS). The Web server retrieves the ASP page and invokes the ASP engine. The engine then interprets ASP code and converts it to HTML, which is in turn forwarded back to the proxy. The proxy was programmed to read and parse HTML files and communicate with Auld Linky. Auld Linky locates keywords that match a given user context (which will be explained in the next paragraph) in a set of linkbases and returns the matching URL and source keywords to the proxy. The proxy replaces the keyword with the URL, which is in turn substituted with the anchor tags. Finally, the request is sent back to the browser and the browser displays the HTML with augmented links corresponding to a given individual user. As a consequence, the user can view the original links hardcoded into the page by the author in addition to links from a linkbase provided by Auld Linky.

The Web site contained nine lessons, of which five were designated for beginners and four for advanced learners, and two linkbases created as part of this experiment namely, beginnerlinkbase, and advancedlinkbase, using the aforementioned FOHM standard, where a link is defined with the keyword, type, and the destination. Links from a linkbase are inserted into the openning webpage based on the user categorisation (i.e. user's knowledge level – beginner or advanced) from the pre-test. For instance, if the pre-test result indicated that a user was a beginner, then only the beginner's lessons would be highlighted with shaded colour to indicate a recommendation for users to commence learning, whereas advanced lessons would appear as if they were hidden links. The user could then select the shaded beginner's lessons which would have all the augmented links from the beginner linkbase. Similarly, if a student was categorised as an advanced learner, then advanced lessons would be actively visible (while the beginner lessons would appear as if they were hidden links) and the advanced links would be augmented in the presenting pages. Nevertheless, if the user decided not to take the direct guidance provided, and instead clicked on their preferred lesson, they would still be able to observe the links in other groups than their own categorisation. Figure 4-3 illustrates the recommended lessons for beginners shaded in yellow, whereas the advanced lessons appear neutral as if there is no link.

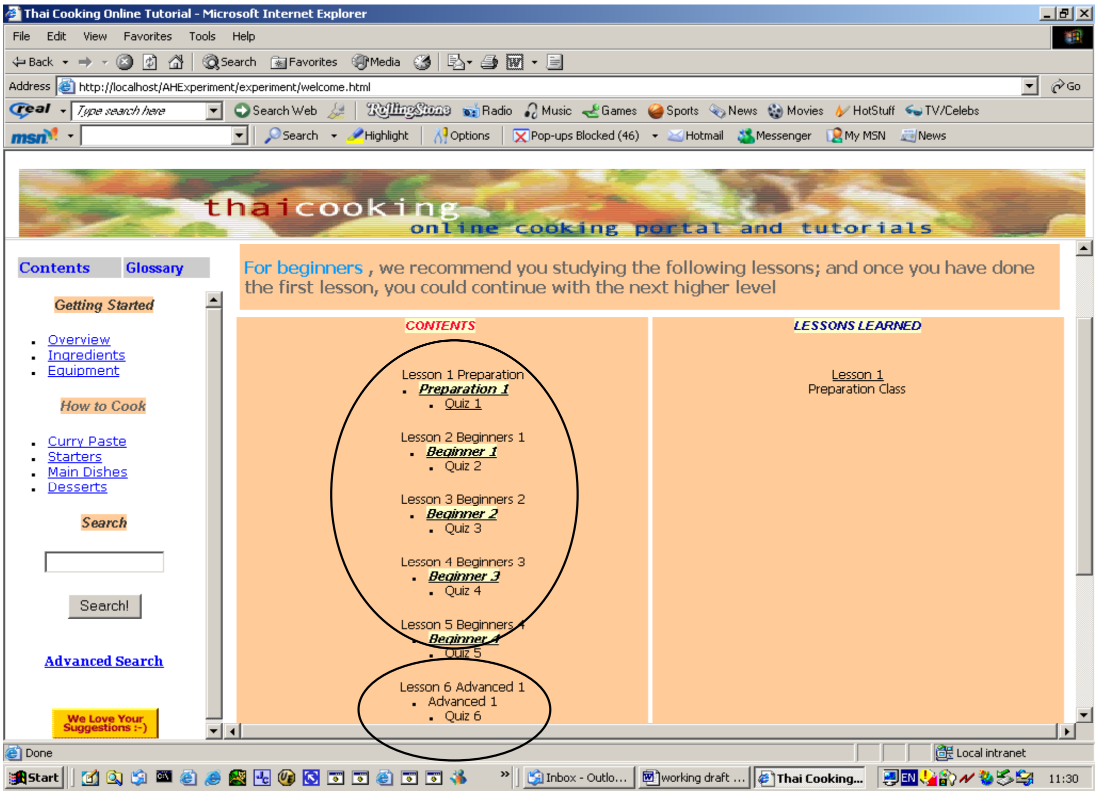


Figure 4-3: The recommended lessons for beginners

In summary, the first experiment enabled the author to have an understanding of how an AH system works and how the link augmentation could be implemented and integrated into an AH system. The next research question was then to investigate and expand the capability of the link augmentation technique to other AH systems.

4.4 The Integration of the AHA! System with the Link Service

The objective of this second experiment was to investigate whether the additional links provided by the link service could possibly function in collaboration with a well-established AH system such as the AHA! system. A Thai-Dutch cookery application was co-written with the AHA! system to explore this issue, in cooperation with Mr Aben, aiming initially at provision of Thai cookery lessons.

As described previously, the AHA! system is aimed at serving as a general-purpose tool to make websites adaptive; however, it does not separate the links from the content which is an area where the link service approach would enable the websites to be authored and maintained more efficiently (Carr *et al.*, 1995). Therefore, it was the hypothesis that the link service approach and the AHA! system should be complementary with one another in making Web-based learning adaptive, and that the combination of the two approaches could be effectively used to build up an adaptive educational hypermedia application.

4.4.1 The Thai-Dutch Cookery Application with AHA!

Section 2.5.4 has generally described the architecture of AHA! and how it functions, this section therefore explains how we implemented our cookery site with the AHA! system – "Thai-Dutch Cooking Tutorial".

To create an AH application with the AHA! system, the following features are required (De Bra and Calvi, 1998a):

- A concept list created by the author.
- Requirement rule for each page.
- A set of generate rules for concept attributes.
- AHA! engine.

We commenced by defining the domain and establishing the concept relationships. Then, the expression rules (or expression requirements) used to adapt the presentation of the page and to update the user model were constructed. At the time of development, AHA! version 1.98 did not come with the authoring tool, therefore the concept relationships and expression requirements had to be completed manually. The concept, as exemplified in Figure 4-4, was constructed based on the concept.dtd that consists of concept name, description, expression, attributes, and resource. Each attribute is composed of name, type, and actions that comprise the conditions for performing the actions, trigger, and assignments. The adaptation rules were written for each concept and stored in xhtml files (Figure 4-5) which is where all the rules are located, each of which in turn indicates their external xml presentation file (Figure 4-6).

```xml
<concept>
 <name>cThaiDutch.Overview</name>
 <description></description>
 <expr>cThaiDutch.Index.knowledge == 0 </expr>
 <attributes>
   <attribute>
     <name>access</name>
     <description></description>
     <default></default>
     <type>3</type>
     <actions>
         <action>
           <expr>cThaiDutch.Overview.knowledge &lt; 100 </expr>
           <trigger>true</trigger>
           <truestat>
             <assignment>
               <variable>cThaiDutch.Overview.knowledge</variable>
               <expr>100</expr>
             </assignment>
           </truestat>
           <falsestat />
         </action>
     </actions>
     <readonly>false</readonly>
     <system>false</system>
     <persistent>false</persistent>
   </attribute>
   <attribute>
     <name>knowledge</name>
     <description></description>
     <default></default>
     <type>1</type>
     <actions />
     <readonly>false</readonly>
     <system>false</system>
     <persistent>true</persistent>
   </attribute>
   <attribute>
     <name>changeable</name>
     <description>This determines that user can manipulate the concept knowledge</description>
     <default></default>
     <type>1</type>
     <actions />
     <readonly>false</readonly>
     <system>false</system>
     <persistent>true</persistent>
   </attribute>
 </attributes>
 <resource>file:/ThaiDutch/xml/Overview.xhtml</resource>
</concept>
```

Figure 4-4: The example of a concept file - ‘Overview’

```
<!DOCTYPE html SYSTEM "../../www.w3c.org/DTD/xhtml-ahaext-1.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<object data="header.xml" type="text/xml">
        Test of an included XML object; this text should not be shown.
</object>
<block>
        <h2>An overview of Thailand and her cooking culture</h2>
        <p>
                <header file="ExternalXML/Overview.xml" print="yes" />
        </p>
        <a href="Index.xhtml"> Back </a> to the main page
</block>
<object data="footer.xml" type="text/xml">
        Test of an included XML object; this text should not be shown.
</object>
</html>
```

Figure 4-5: The Overview.xhtml

```
<!DOCTYPE xml SYSTEM "../../AHAstandard/headerfooter.dtd">
<xml>
        <p>
                // content
        </p>
</xml>
```

Figure 4-6: The Overview.xml

The above statements display the ‘overview’ concept, which automatically activates the Overview.xhtml and its presentation in Overview.xml. When a user visits the overview concept (page), the ‘access’ attribute will be activated as well as its expression. If the expression is true (i.e. the overview concept has never yet been visited), then the Overview page will then be accessed and the knowledge of the user regarding the Overview concept is increasingly assigned to 100 at once (i.e. the system assumes that the user has visited the overview concept and now has the knowledge about this concept.

In addition to the introductory and the learning pages, the learning materials were divided into beginning, intermediate, and advanced lessons, a set of multiple-choice quizzes were constructed to assess how well the user understands the cookery lessons at the end of each knowledge level, i.e. a beginner, intermediate, or advanced quiz. These quizzes will only be active once the user has visited at least two lessons at each level.

However, at this stage returning the quiz results to the user model has not been implemented. Section 4.4.3 will illustrate what the Thai-Dutch Cookery application has to offer.

4.4.2 The Preliminary Integration of AHA! with Auld Linky

A hyperdocument in AHA! consists of XML and XHTML to represent the concepts, adaptation rules and presentation of pages, together with the header and footer which will be included in each page for the AHA! engine to trace the user's progress and the time log when the user accessed the page (De Bra and Calvi, 1998a). This means that the AHA! system can identify the learning progress each user has made and the stage that the user has been working at. To capture the user's progress, the phrase "AHA! Phase" is placed in the header file, as shown in Figure 4-7, to check the current knowledge phase of a user generated by the AHA! engine.

```
<if expr="cThaiDutch_Intro_knowledge&lt;100">
 <block>
  <!-- AHA!Phase := Introduction -->
 </block>
 <block>
  <if expr="cThaiDutch_Beginner_knowledge&lt;100">
   <block>
    <!-- AHA!Phase := Beginner -->
   </block>
   <block>
    <if expr="cThaiDutch_Intermediate_knowledge&lt;100">
     <block>
      <!-- AHA!Phase := Intermediate -->
     </block>
     <block>
      <!-- AHA!Phase := Advanced -->
     </block>
    </if>
   </block>
  </if>
 </block>
</if>
```

Figure 4-7: The use of "AHA! Phase" tag to capture the knowledge phase of the user

A linkbase was created to store all links. Once a user requests a page, the request is then forwarded to the proxy, which in turn will find this AHA! Phase attribute (whether it is introduction, beginner, intermediate or advanced) and query Auld Linky for all links that match the given context (i.e. 'introduction', 'beginner', 'intermediate', or ‘advanced’ links). Auld Linky then returns the links matching the AHA! phase. Figure 4-8 exemplifies a link in the linkbase created for this experiment.

```
<association id="link_001">
<description>This is an example of a link in the linkbase</description>
	<relationtype>supports</relationtype>
	<structure>link</structure>
	<feature>direction</feature>
	<binding>
		<reference missing="variable">
			<locspec>
				<regioncontent>ingredients</regioncontent>
			</locspec>
		</reference>
		<featurevalue feature="direction">source</featurevalue>
	</binding>
	<binding>
		<context>
			<contextvalue key="UserLevel">Beginner</contextvalue>
		</context>
		<reference>
			<data>
			<url>http://localhost:8080/aha/Get/file:/ThaiDutch/glossary/
				ingredients.html
			</url>
			</data>
		</reference>
		<featurevalue feature="direction">destination</featurevalue>
	</binding>
	<binding>
		<context>
			<contextvalue key="UserLevel">Intermediate</contextvalue>
		</context>
		<reference>
			<data>
			<url>http://localhost:8080/aha/Get/file:/ThaiDutch/glossary/
				ingredients_2.html
			</url>
			</data>
		</reference>
		<featurevalue feature="direction">destination</featurevalue>
	</binding>
	<binding>
		<context>
			<contextvalue key="UserLevel">Advanced</contextvalue>
		</context>
		<reference>
			<data>
			<url>http://localhost:8080/aha/Get/file:/ThaiDutch/glossary/
				ingredients_3.html
			</url>
			</data>
		</reference>
		<featurevalue feature="direction">destination</featurevalue>
	</binding>
</association>
```

Figure 4-8: An example of a linkbase in Thai-Dutch Cookery Application

To summarise, a Thai-Dutch cookery application was created using the AHA! system to provide adapted cooking lessons and quizzes based on the user model (i.e. an xml file containing user information such as name, email address, userID, and so on, constructed when the user first registered at the site), and additional links were offered by Auld Linky corresponding to the knowledge level generated by the AHA! engine.

For the later integration and more technical issues, research was undertaken by Millard *et al.* (2003), whose studies revealed that the integration of the two systems had not been completely successful. This is due to the methological differences in the two design styles which caused the conflict in integration. AHA! was created with strictly controlled organisation and design, whereas Auld Linky has taken less deterministic approach where the author has incomplete ability to forecast the navigational options available to a reader at run time (Millard *et al*., 2003). Therefore, although Auld Linky could purely insert additional hyperlinks and the links can correspond to the user's current knowledge phase generated by the AHA! engine, these links were only the external links created separately from the links constructed by the AHA! engine system. This means that these two groups of links function independently from one another, and rather than contributing to each other, they were just two independent entities, which were the probable cause of the link overload problem.

4.4.3 Screenshots of the Cooking Tutorial with the AHA! system

The following screenshots illustrate a user's interaction with the system. First, a user will be asked to supply their registered username and password. If the user has not yet registered then they need to do so before they can enter the site, as shown in Figure 4-9. This information is kept in the user model (UM) or can be stored in a external database.

Figure 4-9: The entry page of the Thai–Dutch Cooking Tutorial

Figure 4-10 depicts the process when the user has logged in successfully. The user will be presented with the ready-to-study lessons (*good links* – the links are shown in blue), which in this case are ‘Readme’ and ‘Overview’. Other two types of links, which will be demonstrated later on, are *neutral links* (i.e. the links that have already been visited), and *bad links* (i.e. the links that are not ready for the user to view).

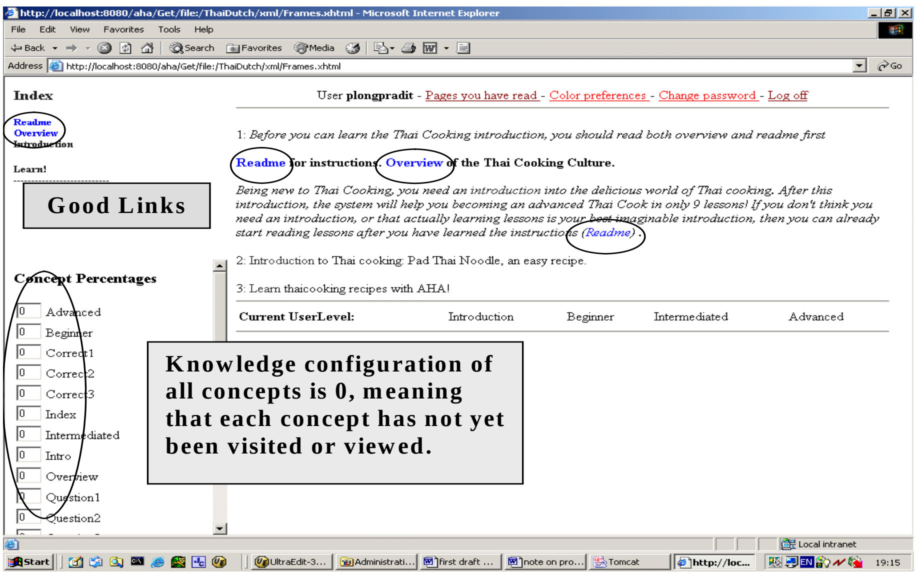
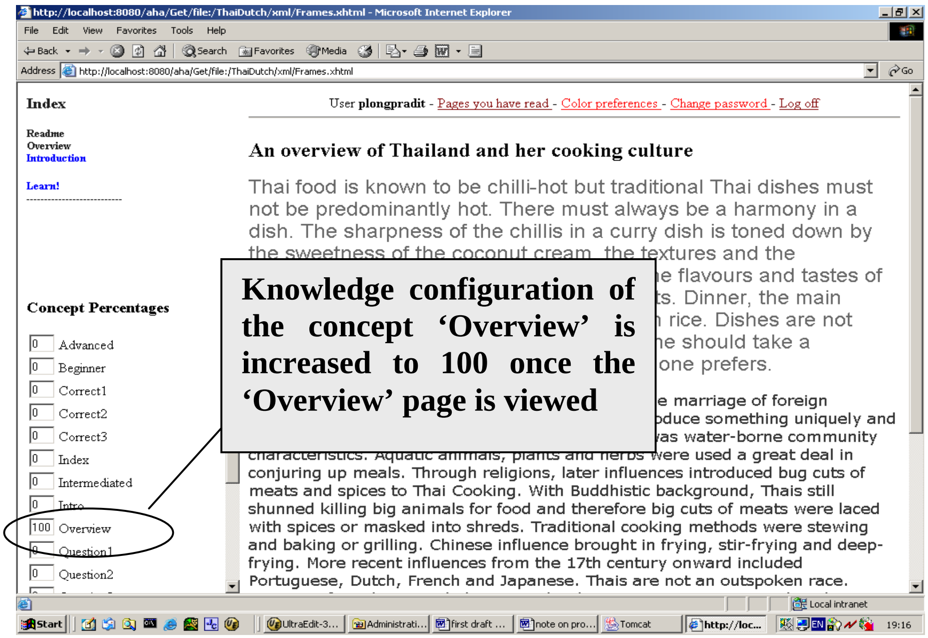


Figure 4-10: The Thai–Dutch Cooking Tutorial: the welcome page

Once a page is visited, the adaptation rules will be triggered, the user model updated, and the knowledge attribute will be increased (as can be seen in the changes in the knowledge configuration menu). As a consequence, the user will be promoted to the next level, the 'Introduction' in this example. The learner has to visit at least one of the introductory lessons in order to be allowed to start learning the cooking lessons, as illustrated in Figure 4-11.



k

Figure 4-11: The Thai-Dutch Cooking Tutorial: the learning page

In our system, we straightforwardly divided our cooking domain into three different levels, namely beginner, intermediate, and advanced, each of which contains three different lessons (Figure 4-12). At each level the user can take the available lessons in any order, but at least two lessons must be visited before the quiz becomes available (Figure 4-13). A set of quizzes – beginner, intermediate and advanced quiz – were developed and each would be triggered at every level (Figure 4-14). Providing that the learner passes the quiz satisfactorily, the user will be able to continue learning the lessons at the next higher level. If the user fails to pass the test, the system recommends that they revise the lessons before retaking the test so as to be promoted to the next level. The student can always come back later to finish the remaining lessons which have not been read at each level.

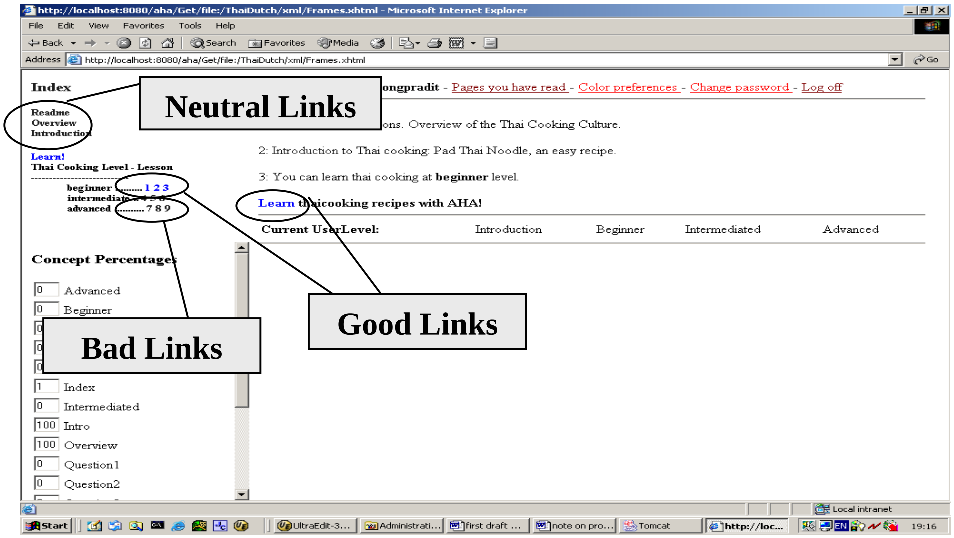


Figure 4-12: The Thai–Dutch Cooking Tutorial: the activation of the beginner lessons

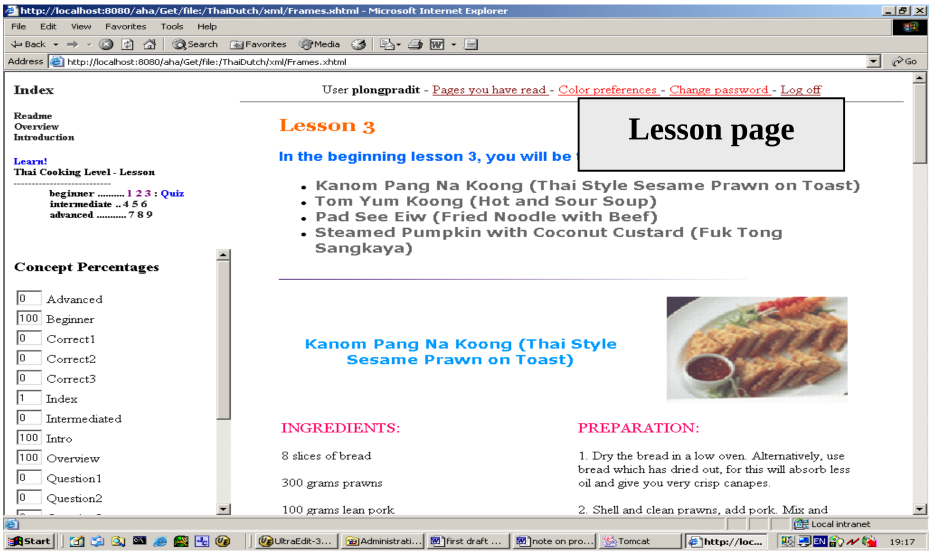


Figure 4-13: The Thai–Dutch Cooking Tutorial: the activation of the beginner quiz

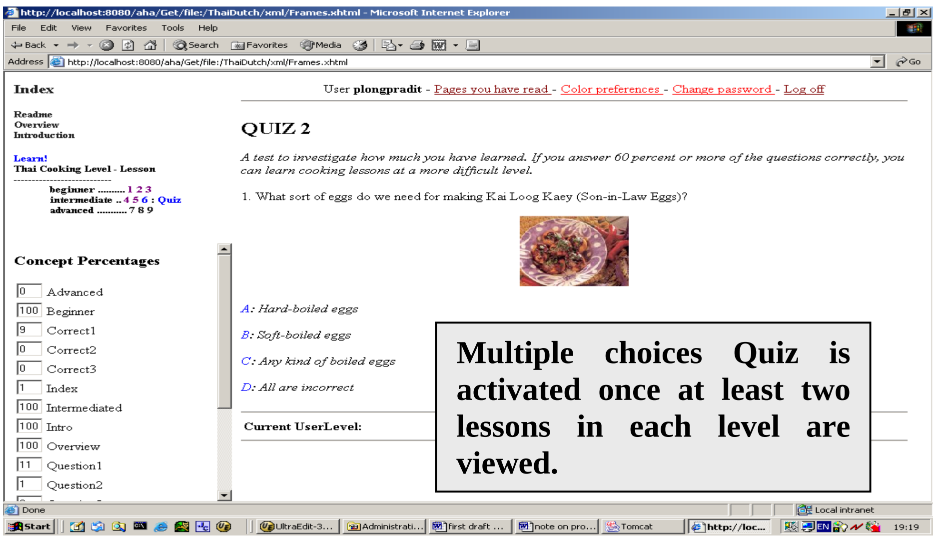


Figure 4-14: The Thai–Dutch Cooking Tutorial: the quiz page

The AHA! system provides the user with the ‘road’ map from which users can view a list of pages which have been visited (Figure 4-15), as well as the colour configuration page (Figure 4-16) which allows users to define the displaying link colours; hence, enabling the link annotation and link hiding techniques. These functions are performed by the AHA! Engine.

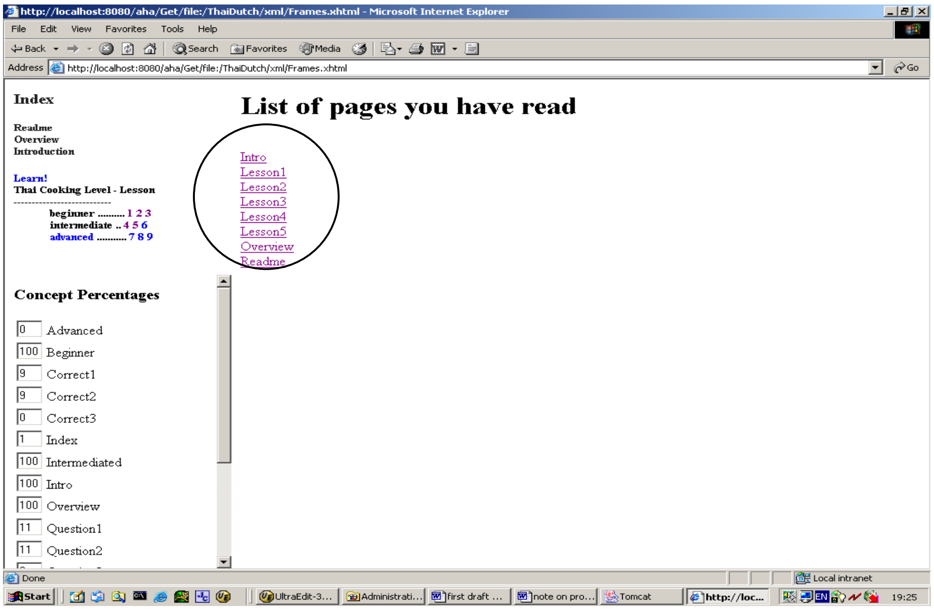


Figure 4-15: The list of pages the user has read

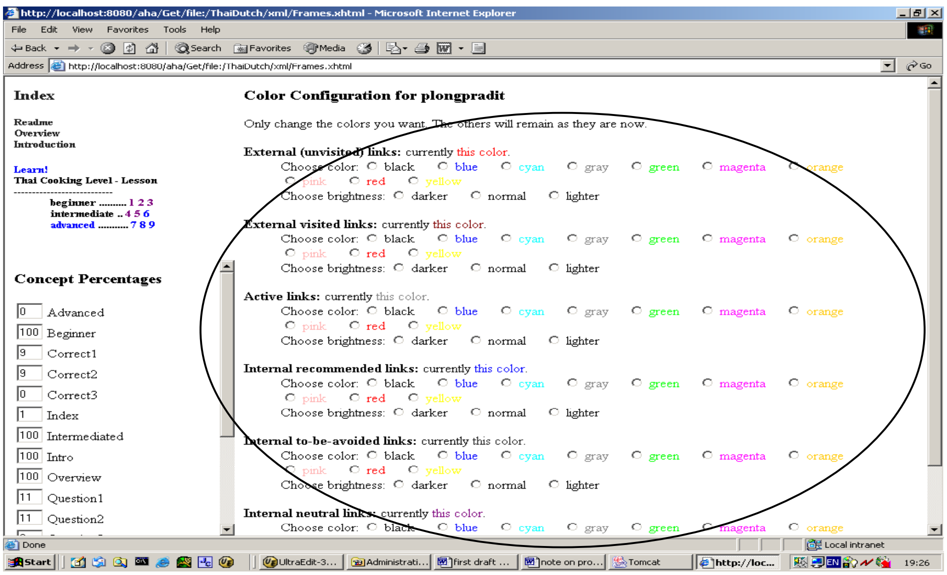


Figure 4-16: The colour configuration page

4.5 Different Dimensions in Linkbases (DDL)

This third experiment was accomplished to address the problem regarding the link augmentation technique and also to propose a new concept of link presentation and classification. The main issue with traditional link augmentation is that users can encounter the problem of having too many additional links (‘prolific linking’) inserted into an existing hyperdocument (Bailey *et al*., 2001; Carr *et al.*, 2002). These links might be irrelevant or out of place when they fail to support the document’s context. One of the solutions to filter out irrelevant links is to use context extraction and analysis (El-Beltagy *et al*., 2002).

Another possible solution might be to consider that a domain generally consists of different dimensions of expertise and these offer dissimilar sets of links stored in linkbases. Considering this approach, the user will be equipped with the ability to tailor their own link visualisation based on their competent dimensions and their level of proficiency. The user might have a variety of expertise and only require additional assistance (which in this case is the provision of additional links) in certain fields. They then do not need to obtain all extra links in every field. This may be particularly practical when there are many different categories of user existing in the context, for instance, novice, beginners, and advanced users (and some stages in between), or there are a number of levels of expertise involved in the subject domain. We termed this as “*the use of different dimensions in linkbases* (DDL) *in providing personalisation of links*”.

To address this issue, the following questions required answering.

- How can different set of links from linkbases be offered to users who have different expertise?
- How can those sets of links be rendered to users according to their knowledge level about the domain, i.e. the less they know about something, the more additional links they should be given?”

The third experiment was carried out in two stages: system requirements and implementation. First, the system requirements concerned the domain preparation (i.e. design of course materials) and link classification based on dimensions. For the matter of preparation of domain, the author expanded the Thai cookery domain and the site was re-engineered to embark on the above issues, as shown in Figure 4-17.

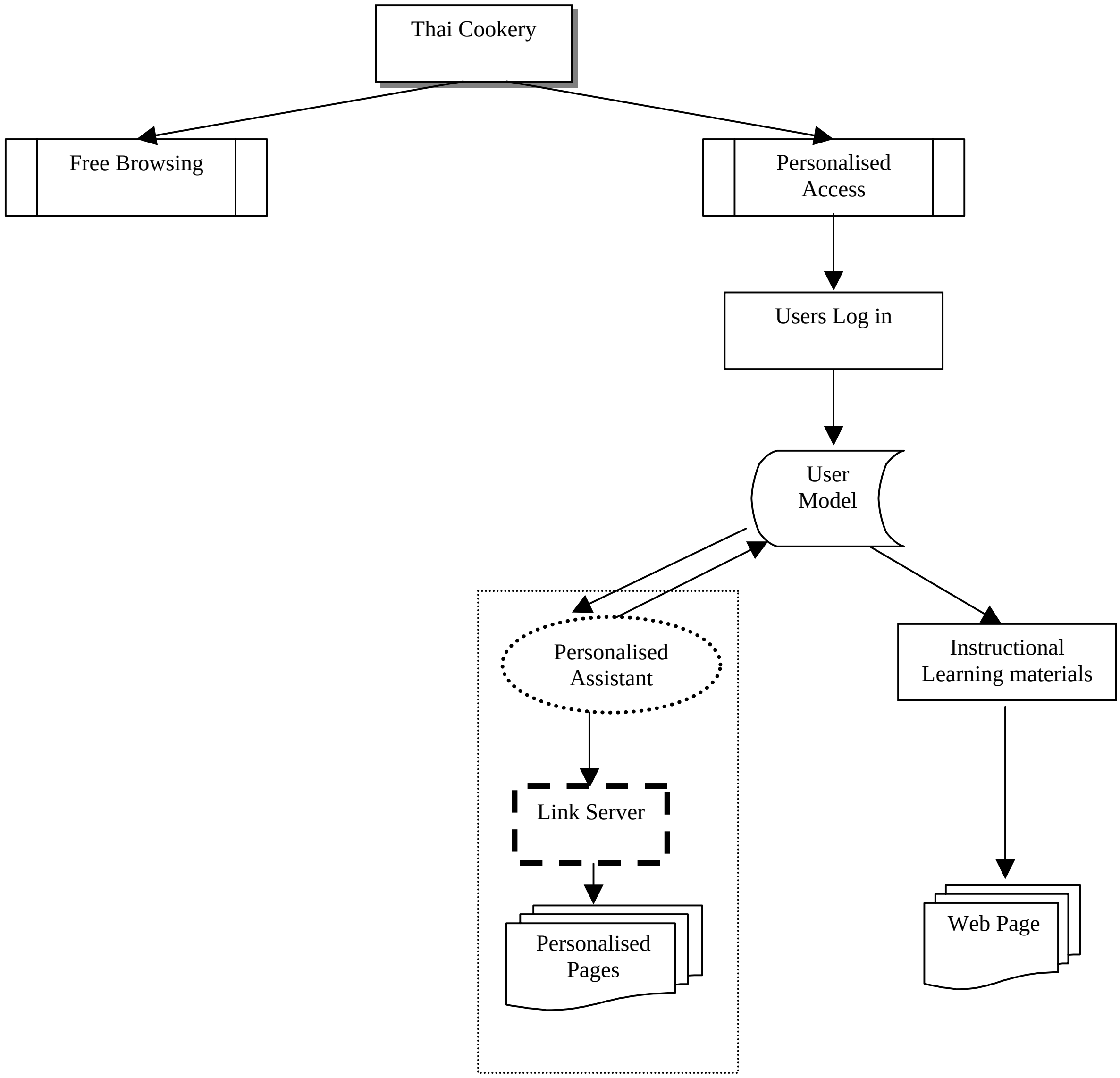


Figure 4-17: The dataflow diagram of a new Thai Cookery site

Within this new approach, a personalised assistant component was implemented. The "*personalised assistant*" module is a user interface – a pop-up window – to allow users to set their own preference of the link visualisation by selecting numbers on a scale of 10-100 for each dimension of their expertise. The greater the number, the more expertise each user has in that dimension. The default score for each expertise dimension is gained from an initial 30 question multiple-choice test; 10 questions for each expertise dimension. The pre-test was straightforwardly designed to guide users on how much knowledge they have in each dimension of expertise. Once the user completes the test, the score will be calculated and used as an indicator to assist them in selecting the right score for each expertise dimension for link personalisation. However, the user can always select and change the presentation of links in relation to their preference and understanding of the given links. It was felt that giving users the control over their own user model was important as it allows them to gain greather understanding of how the system operates (how and why it presents the links) and a feeling that they are in control. The scores for each dimension are kept in different variables and stored in the user model. The personalised assistant will be considered again when the system architecture is reviewed in the next section.

With regard to the *link classification*, this is based on dimensions and sub-dimensions. In general, the domain could comprise *N dimensions*; in this particular case, we chose "*general cookery*", "*Thai cookery*", and "*language*" as the expertise dimensions 1, 2, and 3, respectively. Each dimension could be independently classified into any *M sub-dimensions*.

However, for the purpose of experiment and simplicity, it is assumed that each dimension consists of the same subcategories; namely (from simplest to most complicated) *elementary 1* and *2*, *beginning 1* and *2*, *intermediate 1* and *2*, *advanced 1* and *2*, and *proficiency 1* and *2*. Moreover, the links were manually authored and categorised by the author.

The **system implementation** involved constructing the mechanism for connecting the personalised component with the link server, which will be described in the following section on the system architecture.

4.5.1 System Architecture

The original system architecture from the second experiment, Figure 4-2, has now been expanded to become Figure 4-18 which shows how each component communicates with others. As we can observe, the crucial notion of the personalised module has been put into operation to enable users to select and modify the proportions of expertise in each dimension; to post or retrieve the values of expertise levels in each dimension to or from the user model; and to communicate with the link server which will principally match these expertise values with the context value in linkbases and return the corresponding links. Every time the user amends the expertise indicators when they discover that the previous link augmentation does not actually match their preference or expertise, the previous record in the database will be deleted and updated with the current alteration. These changes take effect immediately, which results in the system being dynamically adapted and the link server providing personalised navigational links based on this recent modification.

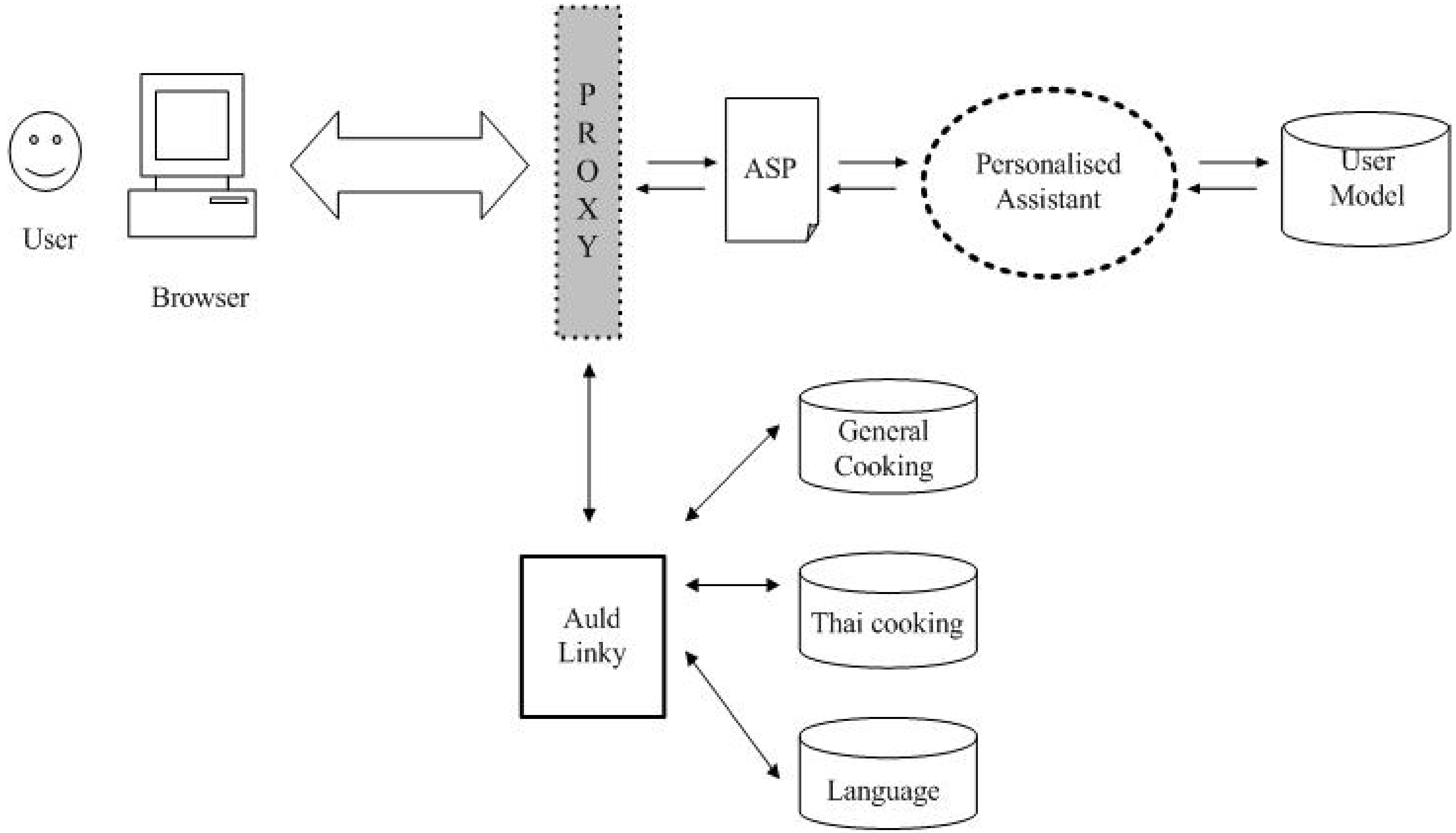


Figure 4-18: The system architecture of a personalised Thai Cookery Web-based application

An individual user profile contains the userID and the score of expertise 1 (General cookery), expertise 2 (Thai cookery), and expertise 3 (Language). These values are dynamically retrieved from the user model. If the record is empty, this means that the user has not yet been assigned the default values from the pre-test and that the user has not yet been able to activate the personalised assistant module; therefore, the expertise 1, 2 and 3 will be assigned to 0 (i.e. there are no links given). However, if these expertise dimension values are not empty, then they will be automatically retrieved from the current record in the database. These expertise dimension values vary from 10 to 100. The *Personalised Assistant* maps these values (10, 20, …100) to string values (elementary 1, 2, … proficiency 2), which can be used by Auld Linky to match context values in its linkbases and retrieve the required dimensional linkbases. Table 4-1 shows the mapping between the values of expertise levels from the Personalised Assistant and string values which will be used by Auld Linky.

10	"elementary1"
20	"elementary2"
30	"beginning1"
40	"beginning2"
50	"intermediate1"
60	"intermediate2"
70	"advanced1"
80	"advanced2"
90	"proficiency1"
100	"proficiency2"

Table 4-1: Mapping between the score of expertise levels and the context in linkbases

Finally, Auld Linky will selectively obtain links matching the above context in linkbases: *expertise1linkbase* (General cookery links), *expertise2linkbase* (Thai cookery links), and *expertise3linkbase* (Language links). The code in Figure 4-19 illustrates an example of a link in the expertise1linkbase containing a keyword, URL, and context value.

```
<association id="link_102">
        <structure>link</structure>
        <relationtype>supports</relationtype>
        <description></description>
        <binding>
                <reference missing="variable">
                        <locspec>
                                <regioncontent>WOK</regioncontent>
                        </locspec>
                </reference>
                <featurevalue feature="direction">source</featurevalue>
        </binding>
        <binding>
                <reference>
                        <data>
                                <url>http://localhost/AHExperiment/…/get_explanation.asp?item
                                Name='WOK'</url>
                        </data>
                </reference>
                <featurevalue feature="direction">destination</featurevalue>
        </binding>
    <context>
          <contextvalue key="expertise1"><!(CDATA(elementary2))></contextvalue>
    </context>
</association>
```

Figure 4-19: An example of a linkbase in General Cookery Expertise Dimension

For clarification, supposing we use the parameters user ID = 10, Expertise 1 (General cookery) =100, Expertise 2 (Thai cookery) = 50, and Expertise 3 (Language) = 20. In the general cookery linkbase any links that hold the context value “proficiency2” will be obtained. Correspondingly, any links that contain the context value “intermediate1” in Thai cookery linkbase will also be acquired. Similarly, in the language linkbase, any links which have the context value “elementary2” will be obtained. Overall, the page will eventually be personalised with the link augmentation technique based on the levels of expertise in each dimension derived from different linkbases.

4.5.2 The Implementation of DDL

This section describes the application of the DDL concept to a personalised Thai Cookery Website and its interaction with the user. As before, users are required to register before entering the site. Once they have registered, the user can log onto the site with the chosen username and password. The system is then able to provide more adaptable features within a more user friendly environment. The user will be presented with the welcome message and a recommendation to take a pre-test (Figure 4-20), which contains three sets of ten multiple-choice questions (Figure 4-21) aiming to elicit the user's expertise level in each different dimension – General cookery, Thai cookery, and Language, respectively.

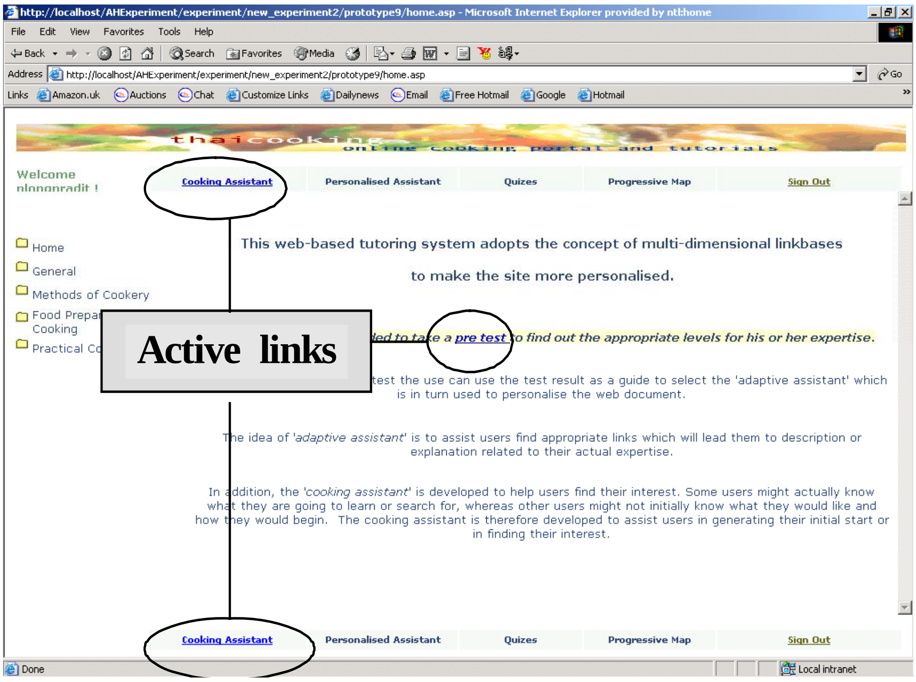


Figure 4-20: The Personalised Thai Cookery site: the use of conditional inclusion to recommend the user to take a pre-test

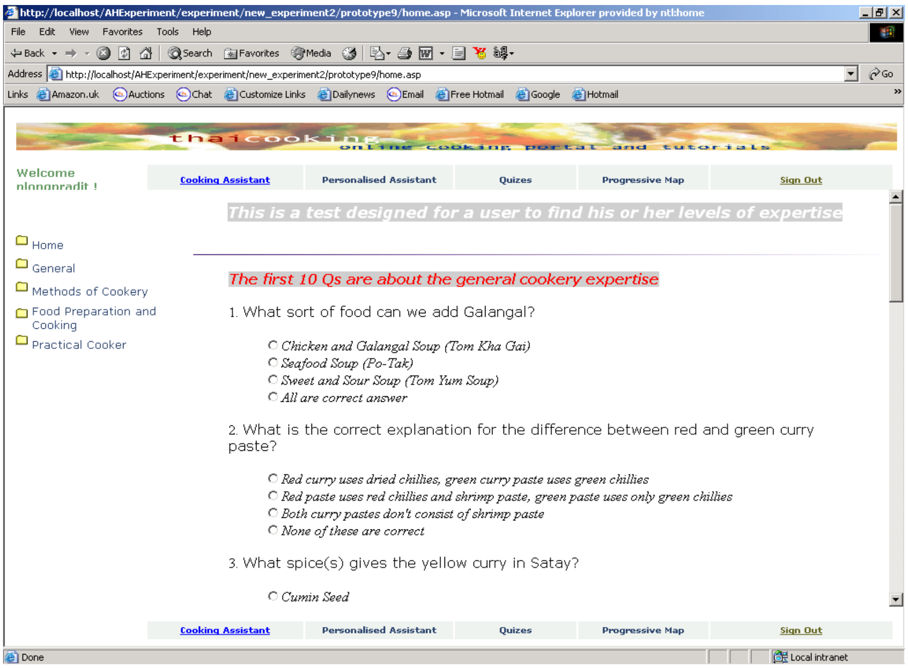


Figure 4-21: The Personalised Thai Cookery site: the Pre-Test Page

The test result assists users in selecting the right score for each expertise dimension for the personalisation of links (Figure 4-22) and these scores will be used as the initial values for link presentation.

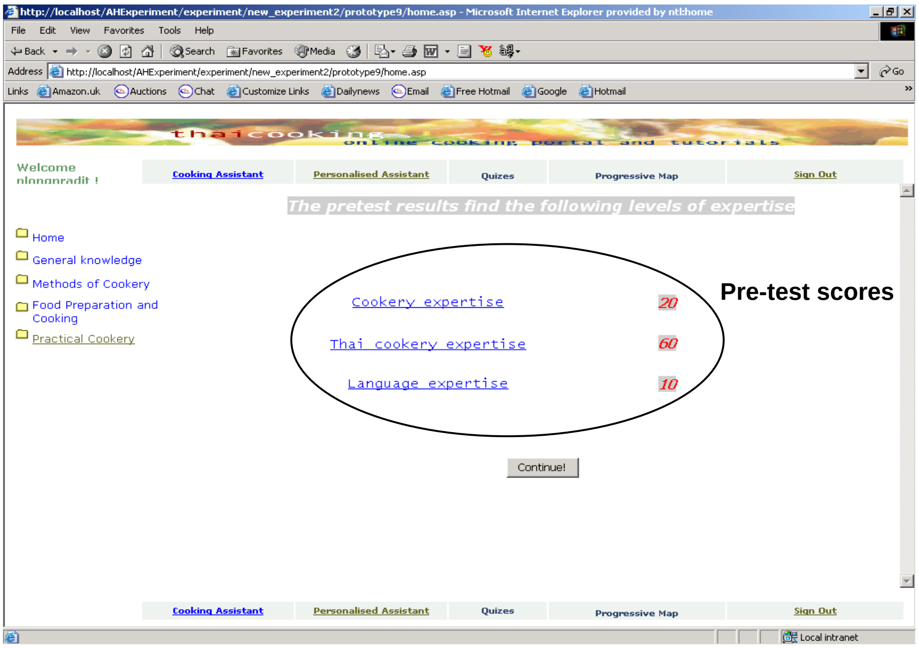


Figure 4-22: The Personalised Thai Cookery site: the pre-test result

The 'Personalised Assistant' component allows users to refine their levels of expertise in each dimension anytime they desire (Figure 4-23). The initial score is dynamically retrieved from the test result that was stored in the database. Once the user clicks the submit button, this will trigger an ASP page which will perform a database update with the new expertise dimensions in the database. This action immediately allows each new page to be automatically updated with the new settings.

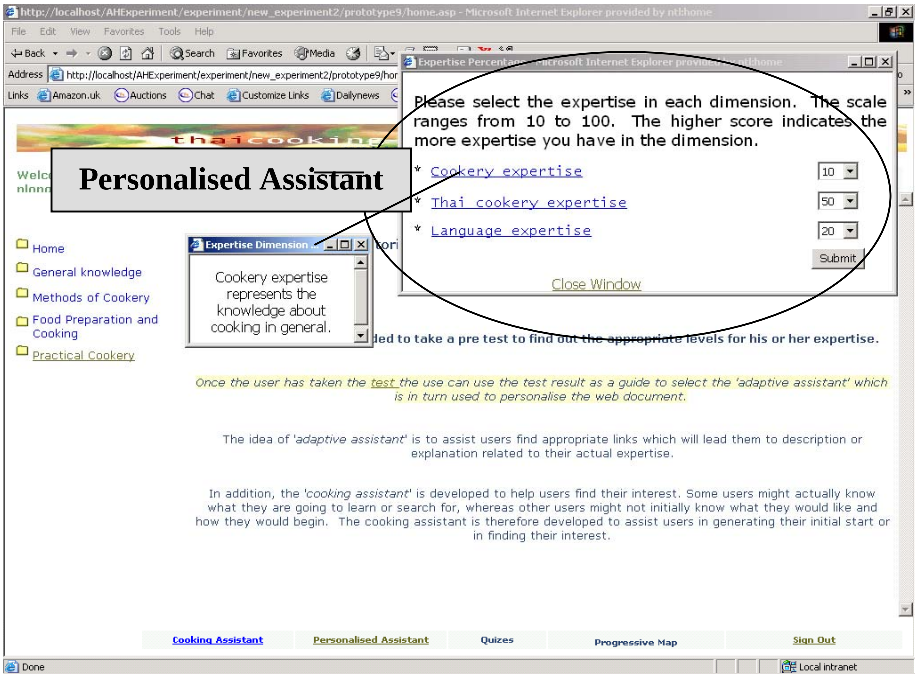


Figure 4-23: The Personalised Thai Cookery site: the 'Personalised Assistant' interface

The link server (Auld Linky) operates by finding the links that match the keywords sent by the proxy. A match is found when the requested expertise level matches the link's descriptive keywords. All the matching links are then returned to the proxy, the proxy replaces the links with the anchor tags, and the links are augmented based on the word in the document matching the link's keywords (Figure 4-24).

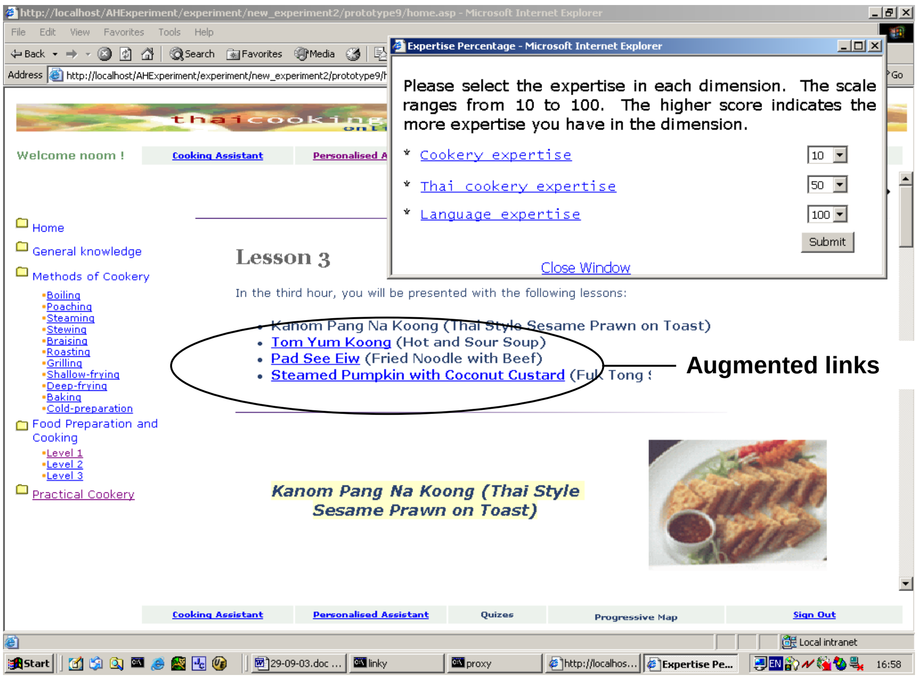


Figure 4-24: The Personalised Thai Cookery site: the page with links augmenting technique

Once each link from the expertise linkbases has been inserted into the page, the user can click on those links to find more additional information. This would then result in another new browser window opening up in order not to distract users' current task in the main window (Figure 4-25).

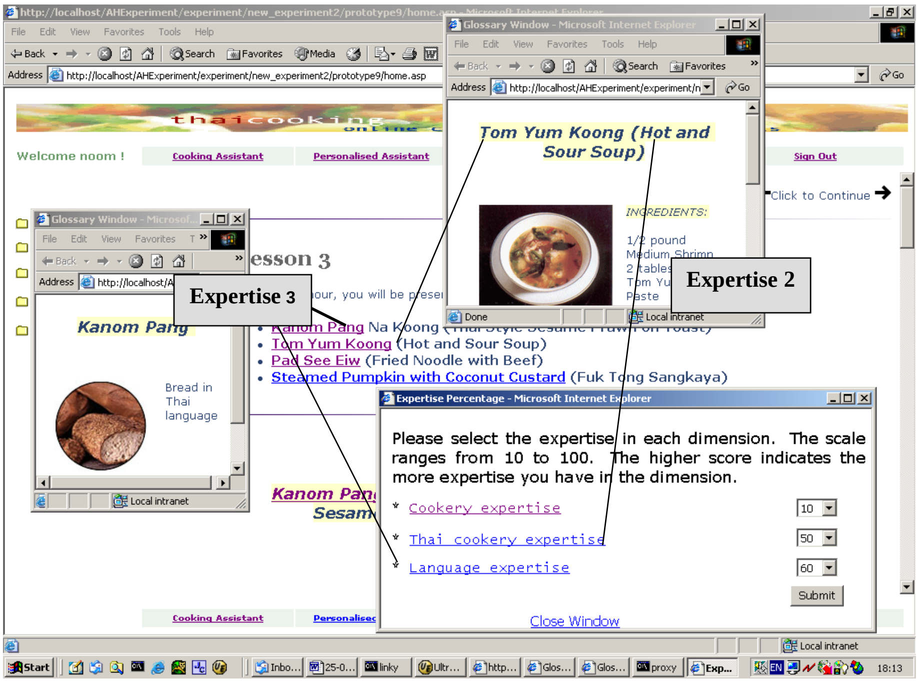


Figure 4-25: The Personalised Thai Cookery site: the augmented links from expertise linkbases

4.6 Reflections on the Initial Work

This chapter documents the initial investigation into adaptive hypermedia and open hypermedia by the author. Link augmentation technique, in particular, was the emphasis of this exploration.

The first system development, Link augmentation with Auld Linky, was aimed at implementing the concept of link augmentation in a selected domain. This enabled the author to obtain practical experience in implementing a simple AH system offering a straightforward approach in link augmentation. The links came from two separate linkbases which corresponded to the user profile.

The second system was designed to conduct a feasibility study in finding if the link service approach could be integrated in collaboration with a well-established AH system like the AHA! System. The preliminary study suggested that Auld Linky could initially provide supplementary links based on the current phase of the user's navigational path generated by the AHA! Engine. In other words, Auld Linky could only offer additional external links after the AHA! engine has already generated the main content and links of the page.

Finally, the third experiment was intended to propose a possible solution to deal with the problem with link overload. Based on the concept that a domain was made up of different dimensions of expertise and each of these expertise dimensions provided different set of links, which were stored in different linkbases, the user was delivered with different sets of links according to his or her expertise dimension and its expertise level. The use of a personalised assistant component to request supplementary links enabled the user to adjust their levels of expertise parameters in different dimensions for links presentation at any time. By allowing users to experiment with and tailor the system at runtime to choose links presentation to suit their preference, irrelevant (generic) links which were not of concern would be filtered out and only the corresponding links would be augmented and presented to the user. Thus, the user would not experience common problems such as too many links were inserted into an existing hyperdocument (‘prolific’ linking) (Carr *et al.*, 2002), a situation when every keyword becomes a generic link (Bailey *et al.*, 2001), and irrelevant or out of context links (El-Beltagy *et al.*, 2002).

Table 4-2 describes a road map of the development of three AH systems. The Thai-Dutch Cookery application with AHA! served as an AH system where the user’s learning (navigation) path was generated by the AHA! engine based on an individual user’s knowledge in the user model, and the link server offered generic links for users to gain more explanation about some keywords in the cookery domain. Although there was the similarity between the Thai Cookery system and the Personalised Thai Cookery Web-based application in that they both provided the link augmentation technique, the latter facilitated users’ control over personalisation of links and its emphasis was on the idea of the implementation of different dimensions in linkbases in provision of link personalisation.

System	AH			OH	
	Adaptive Presentation	**Adaptive Navigational Support**	**User's Control**	**Link Augmentation**	**Linkbase**
1st System: Thai Cookery Web site	Content fragment variants	Link hiding		√	2 linkbases
2nd System Thai-Dutch Cookery application with AHA!	Content fragment variants	Link hiding Link removing Link disabling Link annotation		√	1 linkbase
3rd System: Personalised Thai Cookery Web-based application	Content fragment variants	Link hiding	√	√	3 expertise linbases

Table 4-2: Road map of the development of the three AH system

The developments of the three AH systems provided practical experiences and generated the fundamental issues for the future direction of this work. AH provides users with adaptation of *contents* and *links*; however, the user might find it difficult to control the system's action to make adaptation better work from them. The OH link augmentation technique offers simple adaptation by inserting additional links from a linkbase or linkbases at runtime. The adaptation process is easy to comprehend, and hence to control. However, the traditional problem with this adaptation technique is that it can introduce the link overload problem. Moreover, link presentation from multiple linkbases is not powerful because it involves hypertext authors to make coarse grained decisions about which linkbase a given link resides in. Lastly, representations of one dimension of context as one linkbase fail to support situation when one same link structure can be marked up more than once. That is, a link cannot be annotated as being a member of more than one context, for instance, being for beginners in one context and being for experts in another context. These issues pointed in the direction to this work was going forward.

4.7 Summary

This chapter has presented experiments in development of three adaptive hypermedia systems. OH techniques have been used to provide link adaptation based on the link augmentation technique. FOHM and Auld Linky were used to implement all experiments as a storage format and link provider for the client application which in turn handles the links presentation and personalisation. Each experiment provides grounding and supports the claim that the link service approach can be used as a means to make a website adaptive, particularly for a Web-based personalised navigation system.

The next chapter introduces the concept of a multi-dimensional linkbase and proposes a novel framework derived from such concept which can be used to implement an inquiry-led personalised navigation system (IPNS).

Chapter 5 Multi-Dimensional Linkbase and Inquiry-led Navigation System

5.1 Introduction

The following two chapters document the concept of a multi-dimensional linkbase and its prototype system implementation as proposed to solve the problems with AH and the link augmentation technique described in early chapters. This chapter essentially gives a description of the proposed concept and the inquiry-led navigation system in detail. The next chapter presents the prototype system implementation.

This chapter first revisits the relevant AH and OH concepts and their shortcomings; it then introduces the concept of a multi-dimensional linkbase. Folllowing this, the chapter then concentrates on our definition of an inquiry-led navigation system, and its characteristics. The chapter then elaborates on the rationale for integrating inquiry-led navigation system with multi-dimensional linkbase, together with providing a discussion of types of inquiries the users can perform. Finally, the chapter concludes with the way links were classified and would be presented in the prototype system.

5.2 Revisiting AH and its Shortcomings

As previously described, AH research has taken users' differences in background, tasks, and interests into consideration to provide an enhanced usability of hypertext functionality in terms of adaptation and personalisation based on this individualisation. AH is less about information structure and system architecture, but more about applying its strategies to model their contents and links presented to users, based on their user's profile (Millard *et al.*, 2003). AH allows the same or different information to be presented in a number of dissimilar ways. Early established AH systems and applications were merely centred on the employment of AH techniques: adaptive presentation, or adaptive navigational support, or both, and mainly were developed for a particular domain.

Despite AH techniques providing users with personalisation and adaptation of contents and links, some of the criticisms of adaptive systems are that users do not always understand, or find it difficult to understand, why the system is adapting the contents and links. This is due to the fact that users are not allowed to have control over the system's adaptation process. The user is constrained or limited in their navigational choices, although AH researchers argued that it is not mainly prohibiting but recommending the navigational path whereby users still have the choice to decide upon.

In addition, the fact that different information or different portions of information is presented adaptively to different individuals, is likely to create the 'difference' problem. For example, suppose two users are sitting side by side accessing an adaptive system running on two different machines and providing them with distinctive information based on their stereotype or user profile. If they look at each other's machine and prefer the version they do not have, they cannot do anything about it due to the differences in their user profiles. This is again because they do not have control over the adaptation. Another example is the adaptive system that detects the user's interest, and adapts the contents and links to match that detection. Although the system might recognise the shift of interest the user changes his or her context back and forth, the question such as 'will the user who do not realise the system's action always follow the automatic changes in presentation?' might arise.

Rather than preventing the user from having control over adaptation and personalisation, it is hypothesised that a personalised system which allows user to have direct interaction with the system might provide a sound basis for improving the navigation process. One of the primary objectives of this work is therefore to propose a concept which facilitates users' control over personalisation.

5.3 Revisiting OH and FOHM

The link-orientated view of hypermedia originated from the OH community. The underlying principle of the OH approach is that links are separated from the body of a hypermedia document and stored independently in a link database (linkbase). A linkbase is a set of link structures that have been collected to serve some purpose. For instance, they might represent a similar concept, or topic; a group of users, or a particular user. A link server combines the link structures and content at run-time. OH enables a simple adaptation and personalisation technique by means of selecting hyperstructures that match the context at run time (Millard *et al*., 2003). Link augmentation is an OH technique to insert additional links dynamically into the body of the document. The separation of links from documents provides a number of advantages. For instance, it enables the links to be processed separately from the media they are connected to; different sets of links from linkbases can be dynamically inserted to the document; the original document is not affected when the links are created or modified, or supposing the document is moved around or edited, the original links would still function (Hughes, 2000; Bailey *et al.*, 2001; Bailey *et al.*, 2002). This enhances link management by reducing maintenance workload and increasing authoring capability (Carr *et al.*, 1998).

Despite its advantages, the main problem with the link augmentation technique is the link overload problem. In addition, systems with the link augmentation process provide a linkbase, or a set of linkbases (multiple linkbases), based on representing a conceptually similar rationale as an individual linkbase. This approach does not allow for the situation that a link structure cannot be modelled with separate linkbases. These issues will be further illustrated in the following section with an introduction to the concept of a multi-dimensional linkbase.

FOHM (Millard *et al*., 2001) is a generalised model of hypermedia, which is capable of expressing a number of hypertext domains. Auld Linky (Michaelides *et al.*, 2001) is a FOHM-based contextual link server that accommodates queries for FOHM structures from client applications, analyses the queries that match the pattern expressed in linkbase(s), filters out what fails to match the context via the culling process, and returns the resulting presentation of the context. Together FOHM and Auld Linky can be used to implement the personalisation aspect for an AH or a navigation system (Bailey *et al*., 2002; Abdullah *et al*., 2004, Maneewatthana *et al.*, 2005).

FOHM differs from other OH models in that FOHM is an OH model with contextual structures which can be used to describe the metadata about the hypertext structures (Millard, 2000). The Context and Behaviour object can be attached to any part of the hyperstructure and at several different points in a hyperstructure. This context attachment provides an adaptation or personalisation mechanism by means of defining the conditions of the visibility of the structure. For example, one link can be made particularly visible only to advanced users, whereas another link can be specifically noticeable and accessible only to and by beginner users.

However, there are a number of features of FOHM that have not yet been fully investigated or exploited. This work has used FOHM and Auld Linky as a means to implement a Web-based personalised navigation system and expanded some of the FOHM capability in the following ways:

- FOHM allows for the possibility of n-dimension of context. Despite this, the concept of n-dimensions of context as an n-dimensional linkbase has never been developed, or investigated, and therefore, never implemented in FOHM.
- It may be possible to enhance the context mechanism in FOHM to facilitate the personalisation and adaptation based on an individual user. However, user profiling has never been implemented using FOHM.
- It may be possible to provide semantic representation of concepts or associations of the subject domain as FOHM-based structures. These concept structures can relate to other concepts by means of FOHM links with a set of ontological relationship types. The users should then be able to access this representation of concepts through an interface. This use of taxonomy-based ontology would aid users in the process of querying for a concept and its associated concepts.

The second objective of this work is to present a new application of the link augmentation technique by taking into consideration the link overload problem and a different view of representing a linkbase to support the link insertion process.

5.4 Multi-Dimensional Linkbase (MDL)

As mentioned in Sections 3.3 and 5.3, despite its advantages, the process of link augmentation can create problems with link overload. This is because early applications base their link insertion on a keyword or phrase in the source document, which can lead to common problems, such as:

- Too many links inserted into an existing hyperdocument – 'prolific linking' (Carr *et al*., 2002).
- A situation when every chosen word becomes a generic link (Bailey *et al.*, 2001) and some of these links might be irrelevant or out of place when they fail to support the document's context (El-Beltagy *et al*., 2002).
- Deciding which link to favour in the circumstance of having multiple destination links associated with the same anchor keyword (Bailey *et al*., 2001).

To deal with some of the problems caused by the conventional link augmentation technique, researchers have proposed distinctive approaches. For instance, Carr *et al.* (2002) proposed ontological linking as applied in the COHSE project to deal with prolific linking. El-Beltagy *et al*. (2002) used context extraction and analysis to filter out irrelevant links in the QuIC project. Crowder *et al.* (2000) represented each and every view of a domain as a different linkbase. One linkbase might contain a set of links defined for beginner users and another linkbase consists of an array of links classified for experts. This allows one dimension of context and the user can switch between these multiple linkbases for links presentation by means of a link server. Figure 5-1 demonstrates an example of a traditional linkbase.

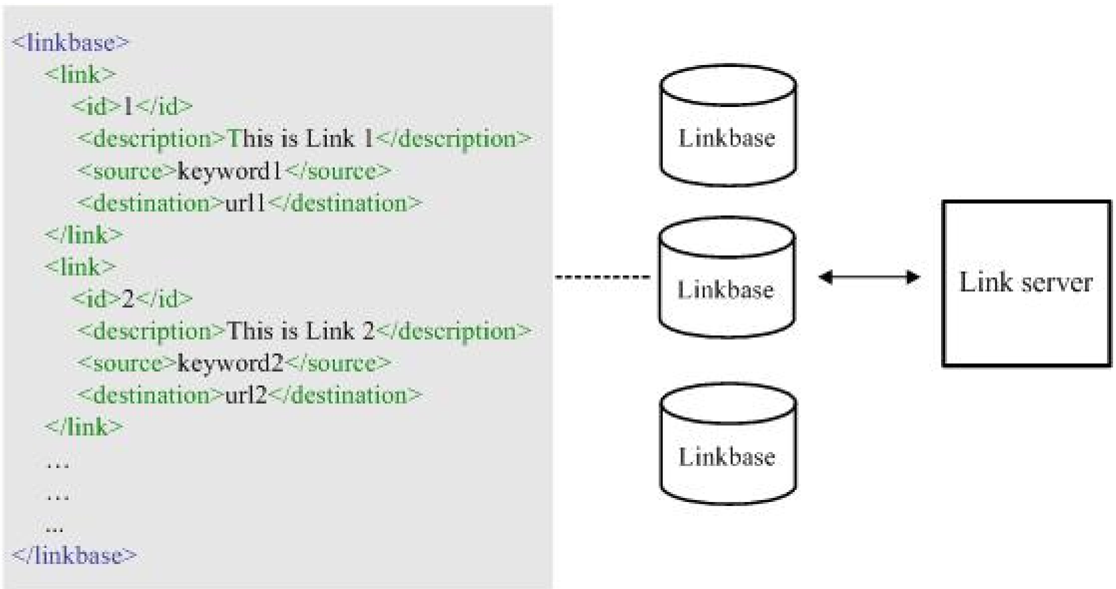


Figure 5-1: Traditional XML linkbase

Multiple linkbases should serve our purpose effectively until situations when the separation of linkbases is impossible, for example, a situation when a link can be annotated as a member of more than one group. That is, a link that is for *beginners* can be placed in a *beginner linkbase*. A link that is classified for *experts* or *students* can be allocated in both the *expert* and *student linkbases*. However, with the traditional linkbase approach, a link that is defined to be visible for more than one dimension, for instance, *beginner students*, has no linkbase to reside.

Another situation that cannot be modelled with separate linkbases is a situation when there is a sub-dimension within a dimension, for instance, a link in an *expertise dimension* linkbase which has a sub-dimension as *'level of competency'* i.e. elementary,…, proficiency.

As a consequence, the need for links in a linkbase to represent more than one dimension is essential to make link personalisation work more effectively, and to provide a finer grained approach than traditional multiple linkbases. Different dimensions in linkbases (DDL), as previously explained in Section 4.5, has provided a grounding for the idea of a Multi-Dimensional Linkbase (MDL).

MDL is a notion that describes a single linkbase containing links annotated with metadata that places the links in several different contextual dimensions at once. These sets of links represent different expertise dimensions, and provide the contextual structure that enables and disables the visibility of links. For example, the domain could comprise N expertise dimensions and each expertise dimension could be classified into M sub-dimensions. Users who are in different dimensions of expertise and possess dissimilar levels of expertise in each expertise dimension should be provided with diverse representations of links from distinct dimensions of expertise. It has taken into account the fact that users with different levels of expertise would require additional information differently in navigation. The user should only view presentations of links appropriate to their level and these links should only come from the user's chosen dimensions of expertise. To elaborate this, supposing a user is a skilled English historian but has no expertise in Asian history; hence requiring different sets of link presentation compared to another user who might be an Asian historian but has limited knowledge about English history.

The implementation of FOHM and Auld Linky can provide mechanisms for presenting contexualised views of hypermedia link structures. Through context objects in FOHM, which can be modelled to contain the dimensional metadata, hypermedia structures can be marked up more than once. That is, a link can be annotated as being for beginners (in expertise dimension), for English speakers (in language dimension), and favouring audio presentation (in media presentation). Within this context, the notion of linkbases that have been annotated using n-dimension of context is termed as 'the use of a multi-dimensional linkbase in providing presentation and personalisation of links based on different expertise dimensions'.

The notion of 'multi-dimension' represents different advantageous, insightful justification. In traditional databases, multi-dimensional database structures have advantages over relational databases in that "*it is more efficient to represent the dataset with a multi-dimensional array rather than a relational table as it reduces the duplication in the relational table, increases performance and provides ease of maintenance*" (Collins, 2003). In the hypertext world, it was deemed that not only is MDL more efficient than traditional linkbases (multiple linkbases, whereby each linkbase represents one dimension of context) in storing link structures, but that (when implemented to support the link adaptation) it also retains the simplicity of adaptation, where the user can see the working behaviours of the adaptive system and the user can configure the link personalisation to work better for them. One of the benefits of MDL and its implementation would be that it could alleviate problems with prolific linking and out of place links while maintaining a user's understanding of the adaptation process.

5.5 Inquiry-led Navigation System (INS)

This section describes our ideal Inquiry-led Navigation System (INS) and its characteristics as well as the reasons for choosing the integration between INS with MDL in detail.

5.5.1 Definition of Inquiry-led Navigation System

We defined our inquiry-led navigation system as: *a system that allows users not only to browse the constructed materials at their own pace, but also to search for information in a goal-directed fashion using the tools provided*. The word **'Inquiry-led'** was particularly chosen and used to denote the *inquiring action* and to emphasise that these inquiry tools were implemented as 'add-on', meaning that the tools can be functional on demand dependent on the user's preference. These tools enable users to pursue more exploratory navigational strategies. Figure 5-2 exhibits how each component in the defined inquiry-led navigation associates with other components.

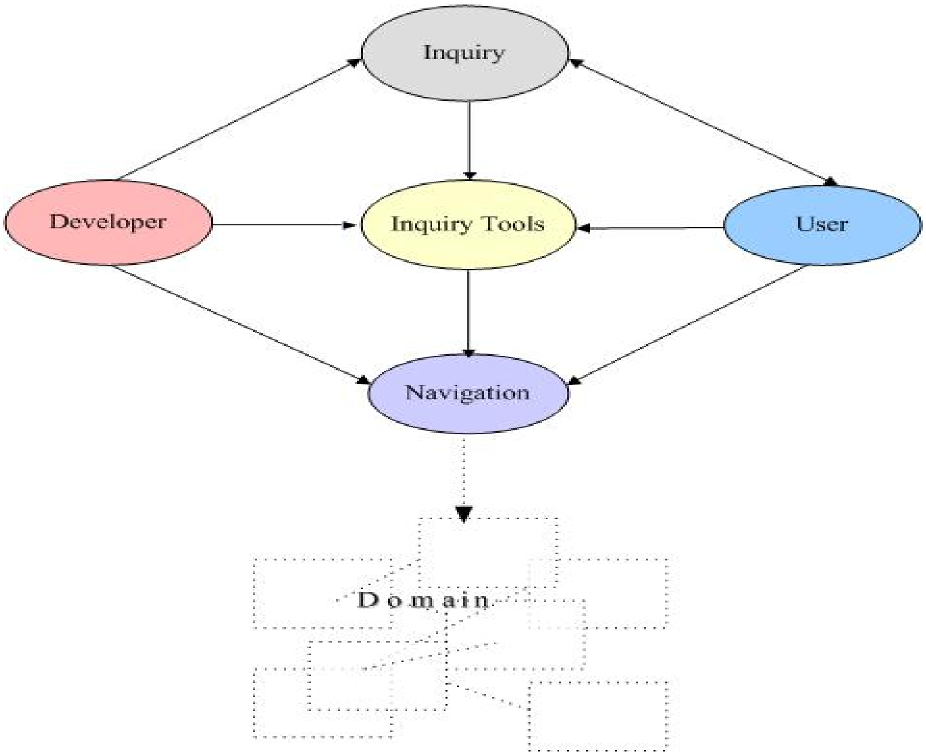


Figure 5-2: An Inquiry-led Navigation System (INS)

As seen in Figure 5-2, a user ( ) has the option of navigating materials either using the inquiry tools, or accessing (or browsing) the materials directly ( ). With the selection of using the tools, the user starts by having an inquiry about something in mind ( ), then conducts his or her search for that particular inquiry using the tools ( ), and the user is then offered the resulting page for navigation. Alternatively, the user can start using the tools straightaway without any inquiry ( ). The diagram shows a two-way arrow between the inquiry and user component, because some of the tools provided can provide a means to observe users' browsing history and can then reflect which topic or concept the user has/has not visited. As a consequence, the users can relate this record to choose their next navigational path. By this way of representation, we value what the user already knows and at the same time we assist them in finding what they might want to be acquainted with. The developer ( ) has responsibilities in constructing inquiries for the user to search, developing and implementing the inquiry tools, and providing the constructed materials for navigation.

5.5.2 *Characteristics of an Inquiry-led Navigation System*

An inquiry-led navigation system based on the above given definition can possess the following characteristics:

- It offers active/self-driven navigation by involving users in the process of making navigational decisions.
- It motivates users with the inquiry tools that are aimed at assisting the user's navigation.
- It provides some degree of learner control.
- Its tools can also serve as scaffolds to support users in the inquiry process.
- It values the experience and knowledge that users possess and bring to the navigational process and at the same time allows them to look for what more they want to know and navigate.

5.5.3 *Why Choose INS with MDL?*

There are a number of reasons why inquiry-led design was chosen to provide the navigation of the proposed system – an *Inquiry-led Personalised Navigation System (IPNS)*, the implementation of the MDL concept into a Web-based prototype system. First, the inquiry-led method promotes active participation of users. It encourages the user to actively be involved in the process of navigation.

Secondly, it enables users to have some sophisticated degree of user control in link presentation and personalisation. User control or 'learner control' is defined as the way the user is allowed to have some control in making instructional or navigational choices (Merrill, 1980; Milheim and Martin, 1991; Lunts, 2002).

As previously mentioned, one of main criticisms of adaptive systems is that the users do not have control of the system's action. The application of an Inquiry-led Navigation System (INS) with the Multi-Dimensional Linkbase concept will therefore not only allow the user to explore the materials, but will also enable the user to inquire and ask for information using the tools the system provides. The user can play around and experiment with the functionality the system has to offer at runtime and observes what comes out, all of which the user can activate or deactivate. The user can configure the setting for personalisation of links back and forth and at any time to choose the best presentation to suit user's preference and the user's expertise dimensions and its level, and the change will take effect immediately. With this approach, it is believed that the users can see the working behaviours of the system clearer and make adaptation work better for them, and hence help to rectify the 'too-many-irrelevant-links' problem.

5.6 Requirements for the Integration of INS with MDL

There are essential aspects to requirements to make possible the integration of INS with MDL – domain preparation, ontology, types of inquiry, and link classification and presentation for MDL.

5.6.1 Domain Preparation

Domain preparation is the process of designing of navigational materials. The baking science and technology subject was purposely chosen as a domain due to the fact that it is a science-based subject that can provide both declarative and procedural information rather than the recipe-like, procedural information in the previous domain of cooking. The domain was designed to cover all essential concepts required in the subject, namely basic food science, advanced science, bakery ingredients, bakery equipment, bakery technologies, bakery products and bakery hygiene, which are organised in the form of electronic textbooks.

5.6.2 Domain Ontology

In addition to the organisation of the content in textbook metaphor, the subject domain was also ontologically subcategorised into smaller **topics**, which were in turn further subdivided into **atomic concepts**. In our terminology, *topics* are a group of ideas that expresses what the subject domain is about, whereas *concepts* are smaller items that make up a topic, and *data items are* smallest atomic concepts that represent a particular piece of information. A *semantic network*, a model for representation of data or knowledge, was created to represent a pattern of associations between topics, concepts and their interconnected concepts (or so called 'concept relationship'), as illustrated in Figure 5-3.

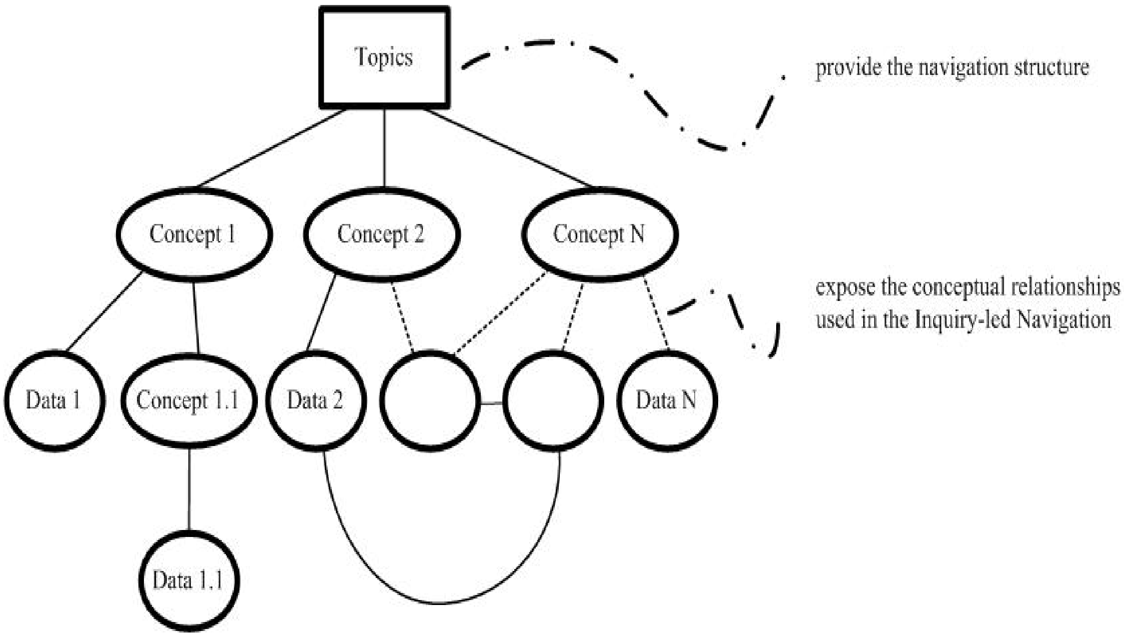


Figure 5-3: Concept hierarchy with ontological relationships between concepts

A *relationship type* allows us to define an established connection and to relate a concept with another concept, or data item (s). There were different types of relationship used in our concept relationships (own defined '**ontology**'), each of which describes the interconnection between concepts and their associated concepts. The 'navigational link' structure in FOHM were expanded to include additional ontological relationship types: *concept relationship, consists of, composed of, have, is/are, tour, level of detail, alternative use, relate to and use in*. The relationship types and their description are given in Table 5-1.

Relationship Type	Description
concept relationship	used when the same concept can be presented with different relationship type which leads to different data items.
tour	sub categorisation of topics into subtopics at top level e.g. chapter 1, chapter 2, ...
level of detail (lod)	to give details for final atomic items (used when an item applies the use of 'consists of' and still needs further categorisation or elaboration) e.g. Soft buns, Hearth Breads, etc. are level of detail (lod) of Specialty Breads.
consists of	describe something consisting of items, but used more generally in other levels than the top level and not chemical decomposition, e.g. Hygiene Programmes consist of four phases.
composed of	similar to 'consists of' and 'level of detail' but used mainly for chemical decomposition e.g. Hexoses composed of Glucose, Fructose, etc.
Have	mainly used when needed to give description about a concept e.g. Carbohydrates have Structure and Properties.
is/are	to give description about a concept and also to answer 'what is/are x?' questions e.g. used after structures, varieties, or properties i.e. Breads have Varieties, and Specialty Breads are a variety of Breads.
alternative use	used to describe the same item perform different functions depending on the product in which it is used e.g. Wheat can be used and perform different functions in breads and cakes.
relate to	to explicitly connect the same concept in one subtopic to another subtopic e.g. topic x relates to topic y.
used in	simply address the user's query such as what this product is used in e.g. this particular moulding equipment is used in French bread making.

Table 5-1: Relationship types and their uses

Figure 5-4 examplifies how a topic and its associated concepts can be ontologically interconnected. The ‘protein’ topic was used for this explanation. The ‘baking science and technology’ domain comprises a number of topics such as ‘basic food science’, ‘advanced science’, and so on. The relationship type which identified the interconnection between the subject domain and its first level topics was the relationship type ‘*tour*’. At the second level, the ‘basic food science’ topic was categorised into smaller topics such as ‘carbohydrates’, ‘proteins’ and so on, which the ‘*tour*’ type was again used to describe the relationship. At the third level, the ‘protein’ topic itself was related to other lower-level concepts, such as ‘structure of proteins’ and ‘properties of proteins’, with the relationship type ‘*have*’. Further, the ‘structure of proteins’ concept had the ‘*composed of*’ relationship type with other three concepts, namely ‘simple proteins’, ‘conjugated proteins’ and ‘derived proteins’, respectively, which in turn each of these three concepts could be broken down into a number of smaller atomic concepts, such as ‘albumins’, ‘globulins’, ‘glutenins’, and so on. Similarly, the ‘properties of proteins’ concept had the ‘*is*’ relationship type with other two smaller concepts - ‘protein denaturation’ and ‘protein hydration’.

Using the semantic network to represent the subject domain this way facilitates the transformation of this concept relationships (‘ontology’) into FOHM structure and result in the performance of the proposed system in inquiry tasks, which will be discussed in the system implementation section in Chapter 6.

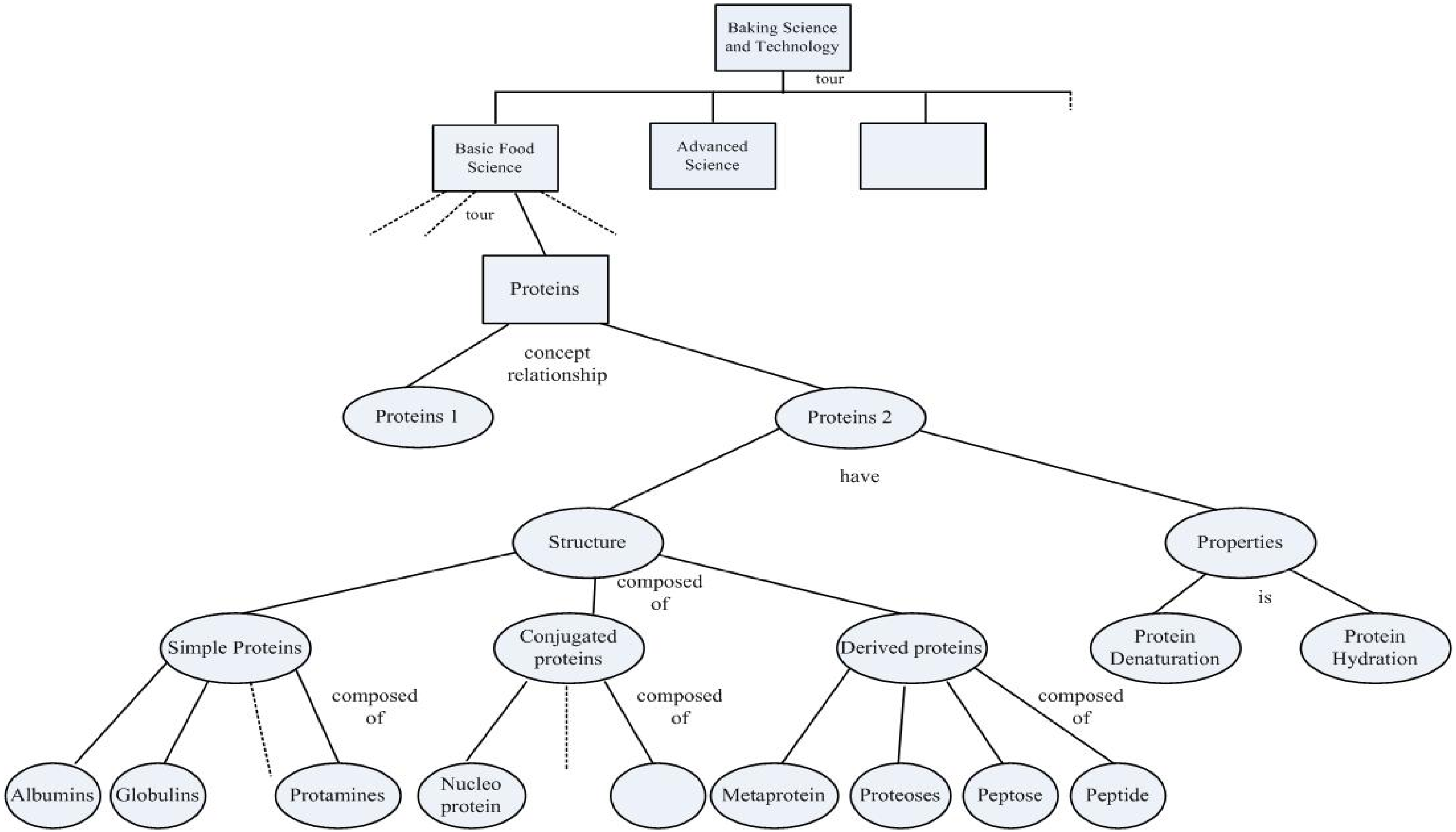


Figure 5-4: Example of the topic 'Protein' and its related concepts

5.6.3 Types of Inquiry

There are two types of inquiry obtainable in the design of the system, namely **concept inquiry** and **keyword inquiry**. *Concept inquiry* enables the user to search for a concept and its associated concepts in the subject domain by using the inquiry interface provided. By this means, users will be presented with the concept and its interconnected concepts in the network. In addition, the user can look for a concept and its connection in the concepts relationship in three different directions, that is, top-down, bottom-up and cross-referencing direction, respectively (Figure 5-5).

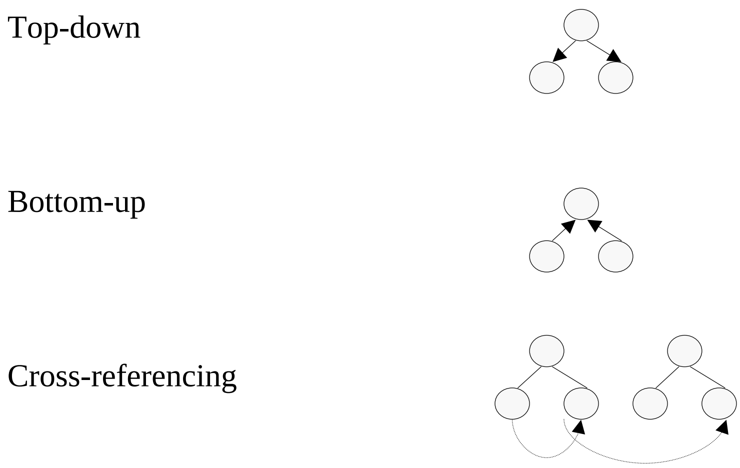


Figure 5-5: Concept inquiry that a user can perform

On the other hand, ***keyword inquiry*** provides the user with the presentation of referential links which give the user additional explanation or elaboration about the particular keyword.

The concept inquiry was applied into the *inquiry link interface*, whereas the keyword inquiry idea can be seen in the *personalised links assistant interface* and the *glossary link interface*. These tools will be discussed in detail in Section 6.4.3.

5.6.4 Link Classification

Although, to date, there has been no attempt to standardise the classification of link types (Ng, 2003), there are a number of proposed link classifications that were mostly based on their own specific hypertext system (Halasz *et al.*, 1987; Akscyn *et al.*, 1988; Fountain *et al.*, 1990). Derose (1989) proposed classification which centred on the difference of links in terms of purpose, structure, function, and preferred means of implementation. For instance, associative links attach pieces of documents based on purposes and they are created on-the-fly by the user, whereas the annotational links represent connections from portions of a text to information about the text with the use of buttons or line markers, and so on.

Other taxonomy is based on the *mechanics of the links* by looking at the number of sources and destinations for links, the directionality of links, and the anchoring mechanism; and *the type of relationships of information being represented* which can be further divided into the relationships based on the organisation of the information space (***structural links***) and the relationships related to the content of information space (***associative*** and ***referential links***) (Lowe and Hall, 1999). *Structural links* provide the structural layout of a domain and do not generally imply any semantic relationships between link information. An *associative link* represents an association between two or more related concepts, or cross-referencing. For instance, users who are looking for the concept x will also be provided with some other documents which will lead them to find out more about the concept x or related concepts. Similar to associative links, a *referential link* serves as a glossary link that provides a link between an item of information such as a keyword and its definition or additional explanation.

In this thesis, the links were classified by ***types of information relationship being represented,*** namely 'structural', 'associative' and 'referential' links (Lowe and Hall, 1999) and ***functions of links***; namely 'expertise links', 'inquiry links' and 'glossary links'. The three links will be further explained in Section 6.4 System Implementation.

Originally, in DDL, as previously described in Section 4.5, links were purely referential links that were classified based on the 'heuristic approach' that the domain comprised 1, 2, 3, …, N expertise or dimensions, and each dimension was subdivided into 1, 2, 3, …, M subcategories. We put the above concept into practice by inventing three separate expertise linkbases that we treated as different dimensions: general cookery, Thai cookery, and language expertise. Each of these dimensions of expertise were further subcategorised into other ten levels of expertise, that is, elementary 1, elementary 2, … , proficiency 2, as depicted in Figure 5-6.

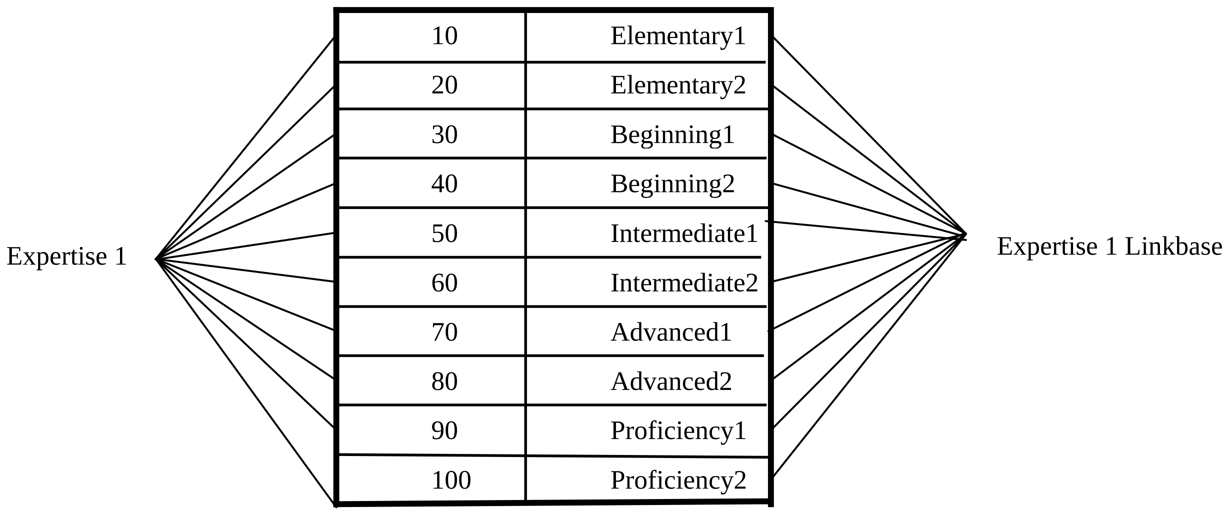


Figure 5-6: Original links classification

However, using this link classification in DDL in the cookery domain, the difficulty lay in that it was rather too idealistic and presumptuous to designate the ten sublevels of expertise. Although these different sets of links from different linkbases could actually provide and be rendered to users with different arrays of expertise in accordance with their knowledge levels, the issue such as how accurate and qualitative the links in each dimension could be sub stereotyped into one particular category and not in another group evolved. This is because the expertise sublevels can overlap each other, and there is no such definite or pragmatic approach that attempts to finely classify these sublevels of knowledge in this particular domain. As a consequence, this created the impetus for a new domain and a better way of classification of links.

Deciding upon a new domain such as Baking Science and Technology was believed to solve the earlier mentioned problem. This is because it is a Science-based subject that provides both declarative and procedural information. The author intended to choose a domain that had nothing to do with IT, but would still be universal to many people. This new domain is also contributing and beneficial to a new aspect of link classification. The former three expertise linkbases in DDL – general cookery, Thai cookery, and language, were modified and transformed, and the proposed MDL concept has been applied to implement the expertise linkbase. The *Expertise MDL* contains three examples of dimensions of expertise – *Subject*, *Language* and *Assessment preference*. In practice, these dimensions can be any N dimension. However, the three dimensions were chosen as the design choice within this work.

The *Subject* dimension encompasses links classified based on the "input-transformation-output" model (Slack *et al*., 1998) (Figure 5-7). The subject domain can now be seen as *food processing operations* which allow the subcategorisation of the Subject dimension into ***raw materials*** (input), ***bakery operations*** (transformation process) and ***bakery products*** (output). *Raw materials* embrace dimensional links that map keywords regarding basic science, advanced science, bakery ingredients, bakery equipment, and bakery hygiene to explanations. *Bakery operations* consist of links that map keywords concerning issues about bakery technologies (i.e. mixing and baking) to explanations. Lastly, *bakery products* define additional links that map keywords relating to bakery products to their explanations. Figure 5-8 exhibits the Subject links classification.

Figure 5-7: The Input-Transformation-Output model (Slack *et al*., 1998)

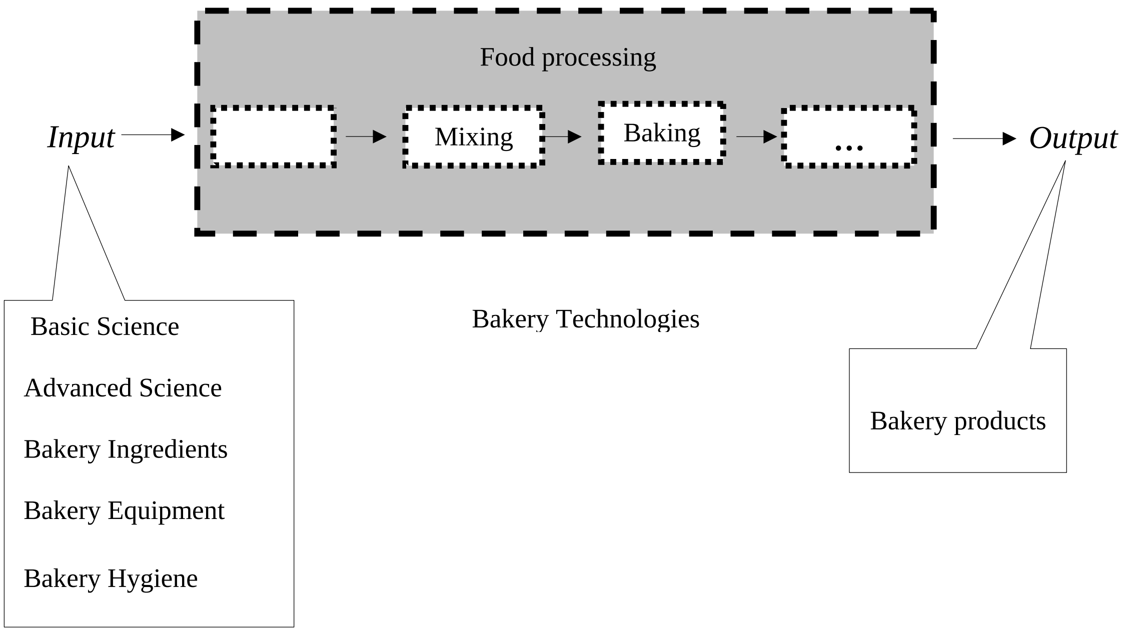


Figure 5-8: Classification of the Subject dimension links

Moreover, two other examples of expertise dimensions are *language* and *assessment preference*. The details about the *Expertise MDL* will be fully explained in the next chapter.

5.6.5 Link Presentation

This section documents the issue about how the links in the proposed system will be presented to the user. A link is selected for augmentation in a document from a linkbase based on the link matching process the link server performs. As explained in Section 4.3, Auld Linky, the link server, is a context-based link server that stores and serves structures expressed in FOHM. It provides the query process via pattern matching and produces the results which are filtered by context value expressed in FOHM structure.

Unlike other methods for link presentation (*stereotyping* and *high-level concept mapping* (Figure 5-9 (a) and (b), respectively) that place emphasis on detecting user interests, grouping them, and generating links from a 'one-fit-all' linkbase or 'one-best-matched' linkbase, links in the proposed system will be presented to the user based on the *direct mapping* between expertise dimensions and their contextual links in an MDL. That is, the user will be provided with the contextual links from the MDL in relation to the user's expertise dimensions.

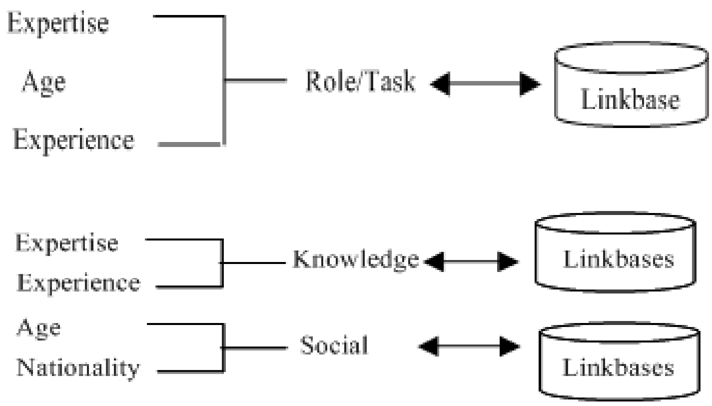


Figure 5-9: (a) Stereotyping and (b) High-level concept mapping

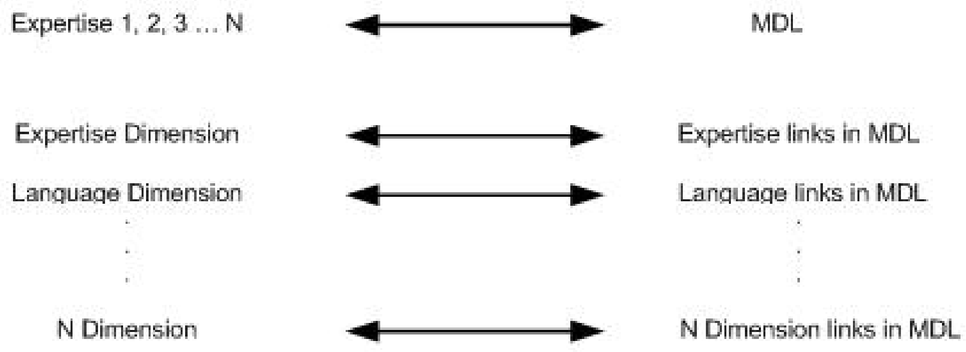


Figure 5-10: Links Presentation with MDL

5.7 Summary

This chapter has presented the concept of a multi-dimensional linkbase as a new application of the link augmentation technique.

The chapter started with revisiting the two research fields AH and OH which play a great role in provision of personalisation and adaptation. Then, the concept of a multi-dimensional linkbase (MDL) was documented, as well as the definition of an inquiry-led navigation system (INS).

MDL is a concept that describes a single linkbase containing links annotated with metadata that places the links in several different contextual dimensions at once. These sets of links represent more than one dimension of adaptation, for instance, to model navigational links to suit users who are in different dimensions of expertise and at different expertise levels. The MDL concept presents a different view of representing a linkbase to support the link insertion process and provides a finer-grained approach for adaptation than traditional 'one-linkbase-per-one-dimension' approach. It is hypothesised that representation of links from different dimensions of expertise, when using to support adaptation behaviour, would enable users to see the working behaviours of the adaptive system; and through this understanding of the adaptive system, the user can make adaptation work better for them, and hence it can help the user to resolve problems with 'too-many-irrelevant-additional links' syndrome.

An inquiry-led navigation system (INS) provides users with exploratory navigational strategies which can function on demand. The reason why choosing an

MDL with INS has also been described. In addition, this chapter has presented the rationales for the integration of MDL and inquiry-led navigation system.

The next chapter will describe the implementation of the MDL concept to prove its applicability, which resulted in a Web-based prototype developed, Inquiry-led Personalised Navigation System (IPNS) .

Chapter 6 Inquiry-led Personalised Navigation System (IPNS)

6.1 Introduction

In the previous chapter, the concept of a multi-dimensional linkbase (MDL) and the inquiry-led navigation system (INS) were individually presented. The system requirements of such integration were also described.

This chapter documents the system implementation of an inquiry-led personalised navigation system. A Web-based prototype system was particularly designed to depict how various components of MDL and INS concepts could be integrated. On the one hand, the MDL approach offers the way the links are classified, generated, and presented according to the user preference and expertise. Based on the direct interaction of the interface design, the user is allowed control over the presentation of the system as they navigate. On the other hand, our INS provides inquiry tools so that users have more guiding and navigational facilities. The chapter will also describe the application of adaptive techniques and other personalised features available in the system.

6.2 Web site Description

The MDL concept has been applied into the development of a Web-based prototype, an *Inquiry-led Personalised Navigation System (IPNS)*.

The IPNS is an inquiry-led navigation system with provision of link personalisation. It is the integration of the concept of a multi-dimensional linkbase (MDL) and an inquiry-led navigation system (INS). The IPNS is a Web-based prototype with an application domain in baking science and technology. It is a re-engineering Web site of previous work, the personalised Thai Cookery site, which provides a more systematic navigation than the recipe-like electronic book metaphor used in the previous system.

As described in Section 5.5.1, the term ‘Inquiry-led’ was selected to represent the inquiring action, and to give emphasis to the inquiry tools, which were implemented as ‘add-on’. That is, the user can use these tools on demand, and when used, the tools will provide users with more navigational facilities that will assist users in their strategic navigation.

The IPNS prototype was developed using the Active Server Pages (ASP) platform, a server-side scripting language, which is a tool for creating dynamic Web pages (Buser *et al*., 1999) and particularly an essential element in building a personalised or adaptive hypermedia system. ASP allows scripts to be embedded into Web pages and these scripts are only activated when the pages are called or requested. Session tracking can also be practically implemented to identify individual users as well as to keep their browsing history during a given period of time. ASP also establishes the mechanism for hiding the tags that are not displayed to the user and allows communication between the Web-based interface and the link server, which results in the visibility and presentation of links in the retrieving page. These features effectively provide a robust platform for our personalised navigation which relies heavily on the connection between the ASP components and the link server.

6.3 System Architecture

This section presents a conceptual overview of the models used in the system. The IPNS comprises four models which are required in any adaptive hypermedia system, namely *domain model*, *navigational model* (or pedagogical model in learning applications), *adaptation model*, and *user model* (Brusilovsky, 1996). Figure 6-1 illustrates the system components and how each operational module is related and communicates with other components in IPNS.

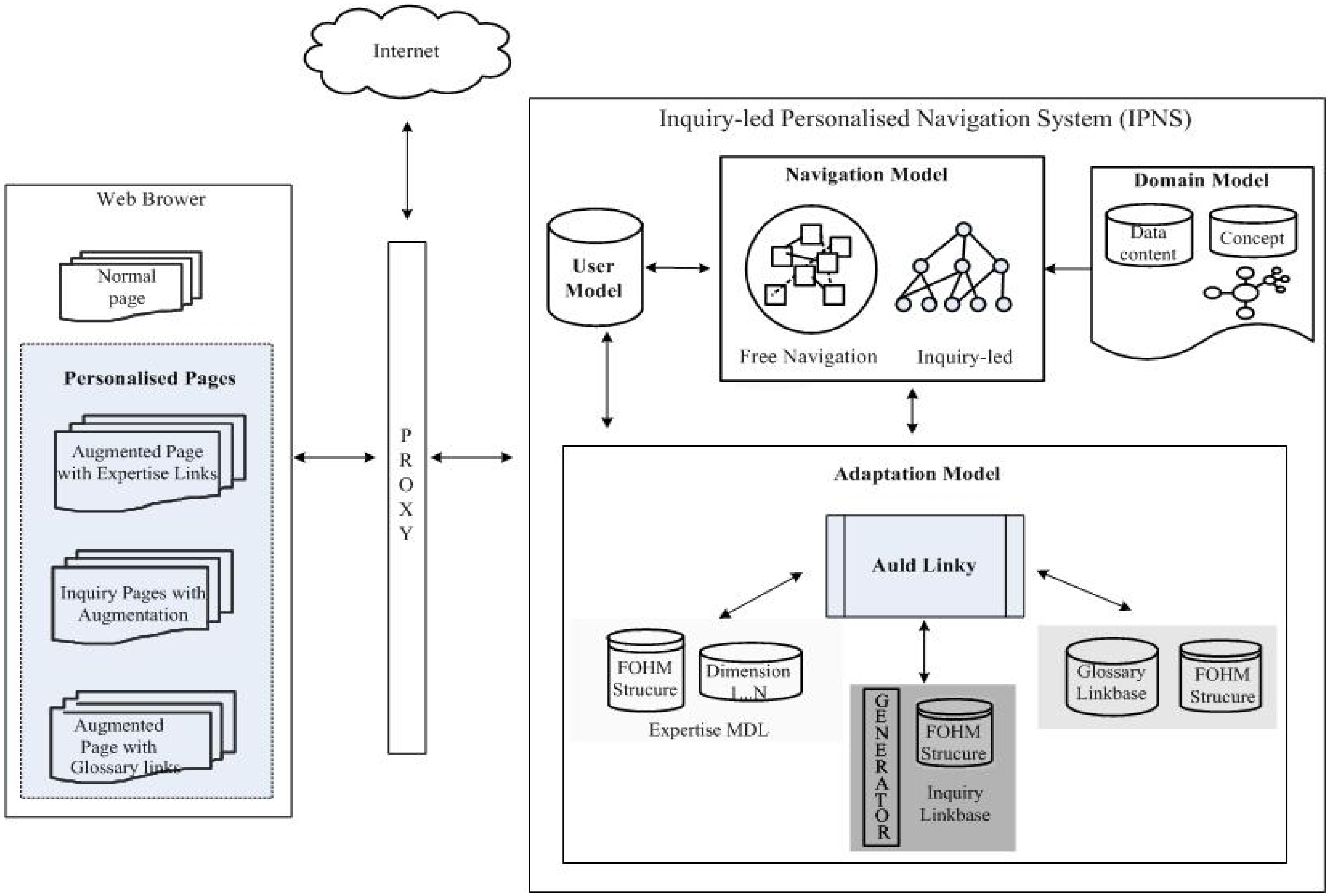


Figure 6-1: The IPNS architecture

6.3.1 Domain Model

The domain model represents how data content in IPNS is organised. The content of IPNS is delivered into two ways to support its navigational module: *electronic textbook* (E-book) and *concept relationships* (or specifically defined ‘ontology’).

The domain of Baking Science and Technology was purposely chosen to represent a subject domain, which in fact could be any other subject. This is because the author wanted a subject that had little to do with IT, yet would still be familiar to many people. Baking is a universal subject and of a number of people’s interests, and with the addition of science and technology, it can offer a rich and systematic domain. Furthermore, baking technology can be viewed as a food production operation, which concerns raw materials (input), food transformation process (mixing and baking), and products (bakery products). This idea in turn enables us to apply a model for classification of links and also allows us to think of different skills within the subject domain as different dimensions of expertise, for instance: expertise about raw materials, operations, products and food hygiene.

As described in Section 5.6.2, in addition to the E-book metaphor, to facilitate Inquiry-led (or exploratory) navigation, the domain was modelled as a concept hierachy with additional ontological relationships between concepts. The subject domain was broken into smaller topics and concepts whereby each concept was related to another concept or data item by means of a FOHM link with one of a set of established relationship types. Users can access this domain ontology through an inquiry interface. Figure 6-2 (a) exhibits the data content in electronic textbook (E-book) metaphor, and Figure 6-2 (b) demonstates the data content from the domain ontology.

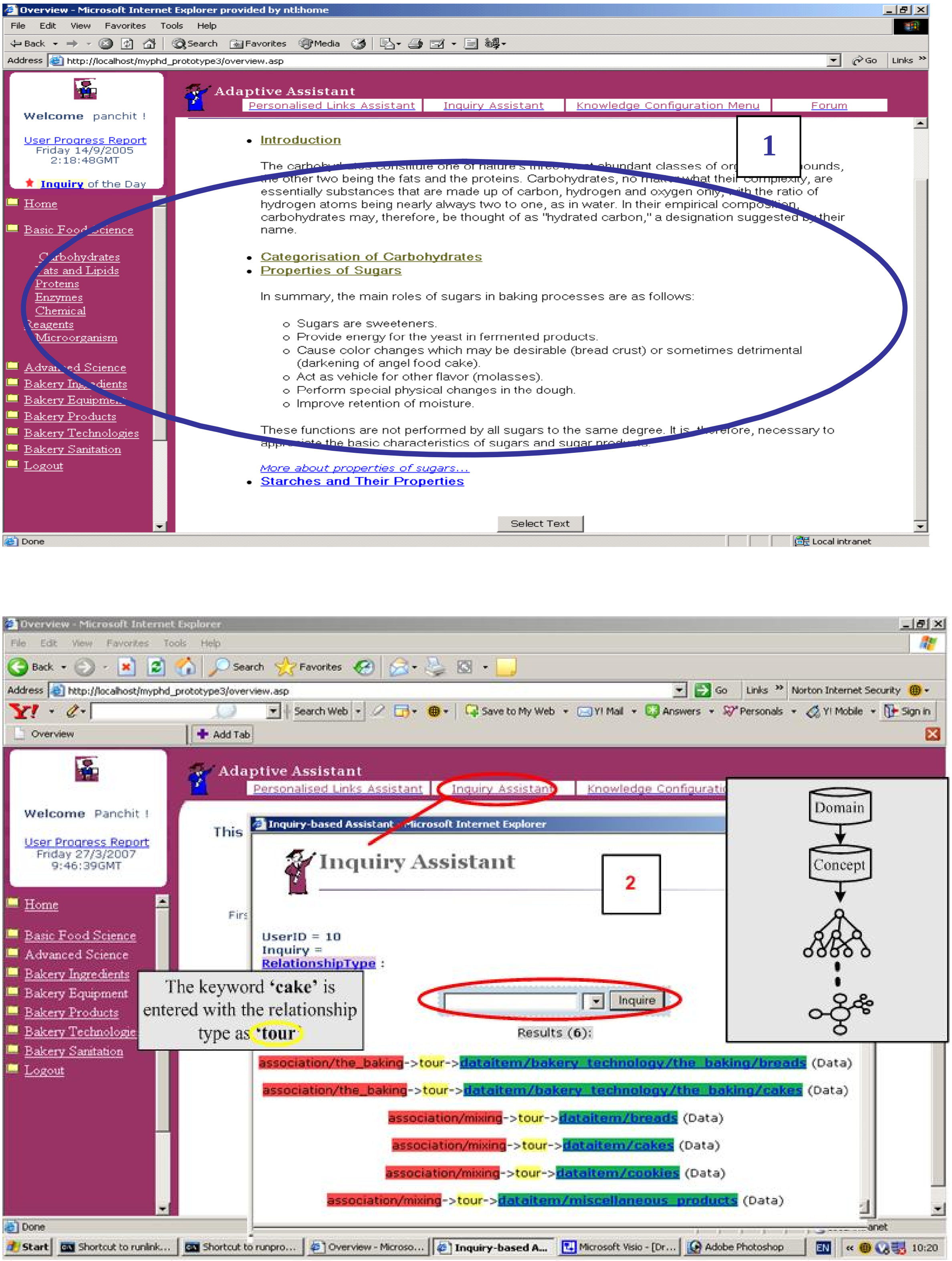


Figure 6-2: (a) The *E-Book* data content in IPNS and (b) the content from *Domain Ontology*

6.3.2 Navigational Model

The navigational model is concerned about the way users are enabled to navigate the information space in IPNS. As illustrated in Figure 6-1, the communication between the domain model and the navigational model can be made with two means: *free navigation* (browsing through the electronic textbook) and *inquiry-led navigation* (navigating with the aid of inquiry tools (Figure 6-3). The first method of navigation allows users to browse the material in an informal way at the users' pace. Inquiry-led navigation facilitates the navigational channel when the user selects one of the inquiry tools provided to support their process of navigation. The user has the option whether or not to use the assistance from the presenting tools. These tools were designed to assist the user with more navigational strategy, for instance, providing a means to personalise the presentation of links, finding what topics/concepts they are looking for, and looking for more links for related or associated topics or concepts. The inquiry tools will be described in detail later on in the chapter.

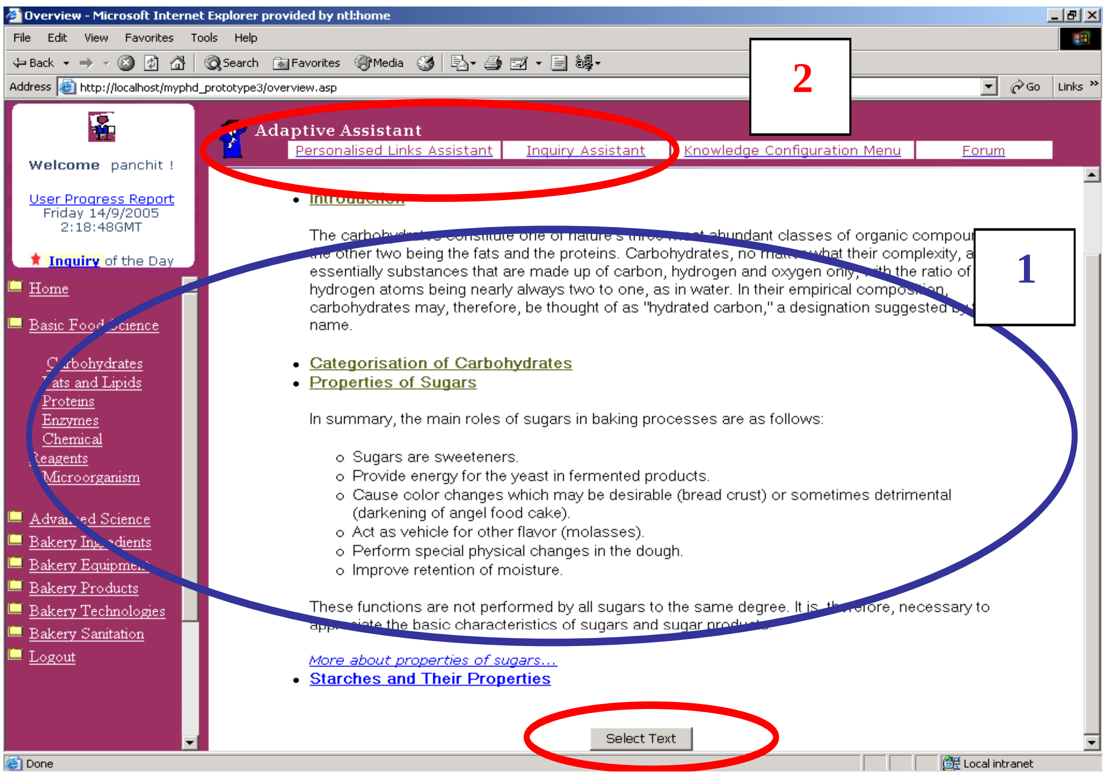


Figure 6-3: The Navigational model in IPNS – Informal Browsing (1) and Inquiry-led Tools (2)

6.3.3 Adaptation Model

The adaptation model deals with the navigational interfaces, link augmentation and the personalisation of links. As shown in Figure 6-1, it is an intermediary component that draws the navigational module and the user model together. It comprises three essential blocks of components: *personalised links assistant module, inquiry links module*, and *the 'follow links' module*. Figure 6-4 describes how each adaptation component interacts with the navigation model and the user model.

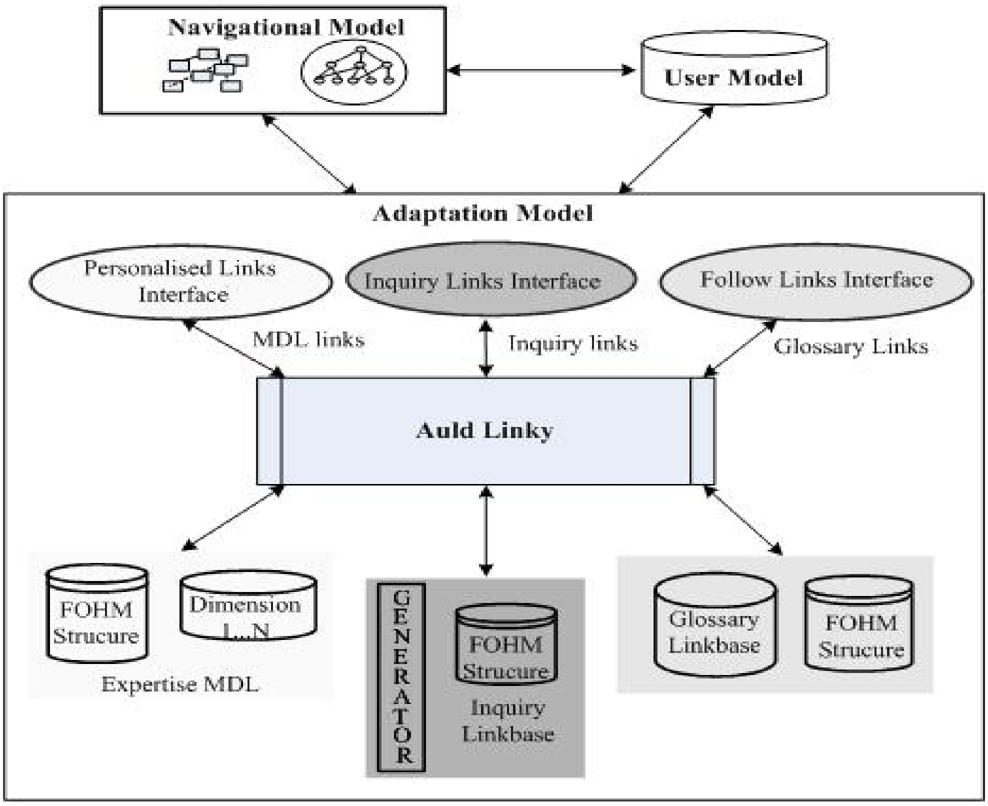


Figure 6-4: Adaptation Model

Personalised Links module concerns presentation and personalisation of links from MDL.

Inquiry Links interface is about links presentation based on the defined ontology.

Follow Links module is centred on links presentation based on the Microcosm (Fountain *et al*., 1990) philosophy which allows users to look for links to follow for a particular topic or concept.

Auld Linky provides appropriate views on linkbases (*Expertise MDL*, *Inquiry Linkbase*, and *Glossary Linkbase*) using its culling process and returns the relevant links matching a given context.

The adaptation model provides the core for links personalisation and presentation and will be further explained in the system implementation.

6.3.4 User Model

For any personalised or adaptive system to keep track of users, their personal details such as username, background knowledge, etc., will initially need to be captured. The role of the user model is then to establish the personalisation for an individual user. It functions by keeping the record, processing and retrieving the captured information about the users.

In IPNS, the system initially stores a record of the user's general information such as firstname, lastname, date of registration, email address, username and password. Once the user has finished his or her online registration, the user will then be asked to select their initial setting of the levels of expertise – *Subject expertise* (raw material, bakery operations, and bakery products expertise), *Language expertise*, and *Assessment preference*, as shown in Figure 6-5. This selection serves as a means to assign a preliminary value to the user model of that particular user, which will then be used for his or her personalisation of *Expertise MDL* links. Throughout the navigation, users are allowed to refine their levels of expertise, the user model will then be dynamically modified and updated according to this modififcation. The amendment of these expertise values will take effect immmediately and result in new links augmentation into the page. The user takes control in setting the presentation of the Expertise MDL link augmentation to suit his or her levels of expertise and preference.

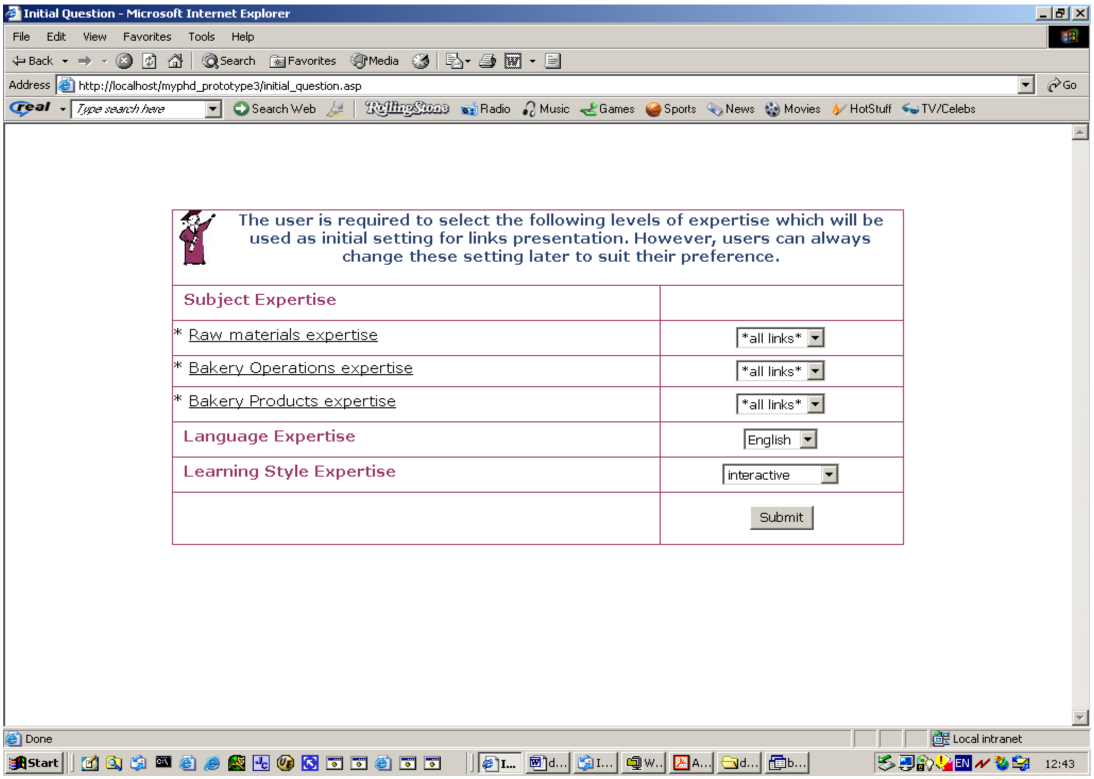


Figure 6-5: The initialisation of the user model

6.4 System Implementation

In this section, the system implementation will be described, particularly the Adaptation Model. The implementation of the adaptation model was focussed on the personalisation of links by means of the link augmentation technique. This process incorporates issues such as multi-dimensional linkbase(s) (MDL(s)), link structures within IPNS MDL(s), Inquiry-led tools and mechanism for connecting the personalised components with the link server.

6.4.1 Multi-Dimensional Linkbase(s)

As previously described, the concept of a multi-dimensional linkbase is centred on the representation of link visibility in different contextual dimensions. The MDL concept stores a set of links in a single linkbase, where these links are annotated with metadata and placed in different contexutual dimensions at once. Within this approach, it allows for the situation when the traditional multiple linkbases – *one-dimension-per-one-linkbase* approach, become impractical.

The MDL concept has been used in the development of the IPNS. In addition to the Expertise MDL, we have introduced two more linkbases: namely, *Inquiry* and *Glossary*. Although these are implemented using the same structures, they are not multi-dimensional in the current implementation. This issue can be looked at in future work. Both were designed to offer the user more navigational functions. Figure 6-7 exhibits an overall picture of how distinctive sets of MDL and linkbases are provided in the system.

The MDL and two linkbases were created in three independent linkbases to separate their functionality from one another. Although providing similar functionality, i.e. the link augmentation process, these linkbases were also designed to deliver divergent rationales. In addition, although their similar mechanisms in connection with the link server are centred on the identification of hidden value tags, the functions to be called at run-time are different. Last but not least, separation of these three diverse types of linkbases support ease of authoring and maintaining the links stored in individual linkbases.

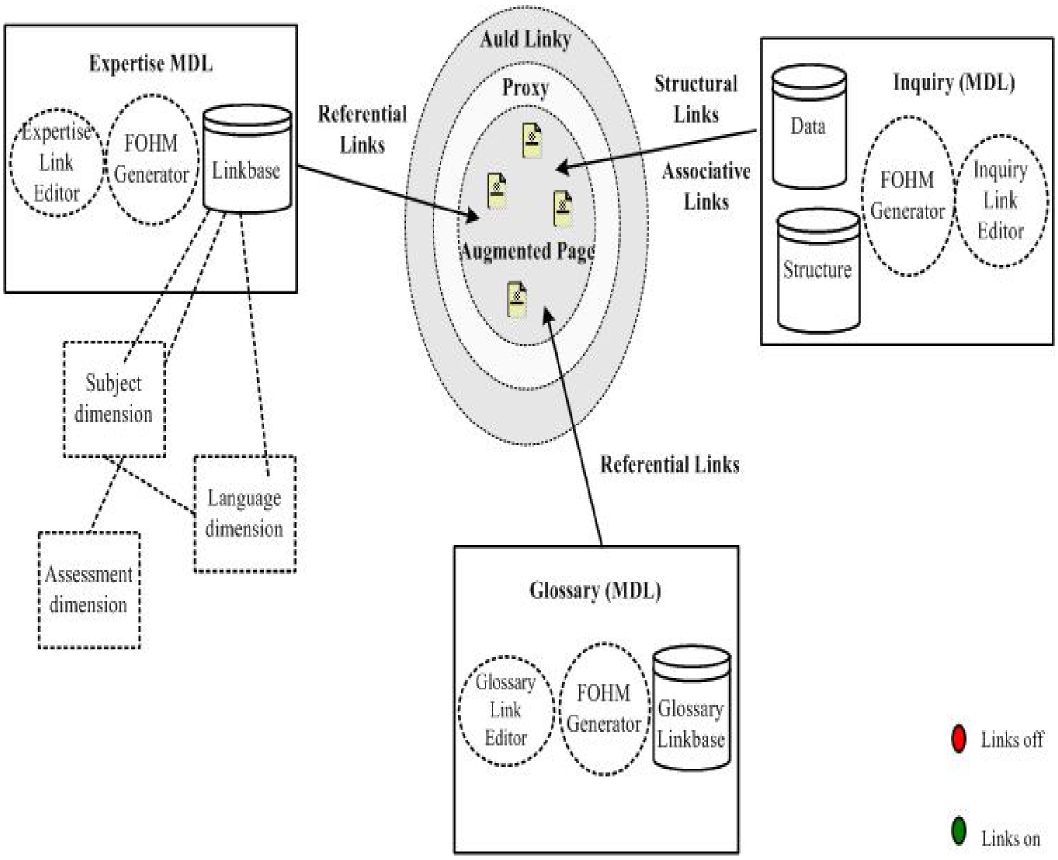


Figure 6-6: Multi-Dimensional Linkbase (s) (MDL(s))

The ***Expertise MDL*** comprises referential links that relate a keyword in a context to its additional elaboration or explanation. As can be seen in Figure 6-7, the Expertise MDL encompasses three examples of dimensions of expertise – *Subject*, *Languag*e, and *Assessment preference*. These expertise dimensions in practice can be any N dimensions.

- The *Subject* dimension in particular was classified based on the input-transformation-output model, as previously explained into three sub dimensions, namely *raw materials* (the input to the operations, i.e. basic and advanced science, bakery ingredients and equipment), *bakery operations* (issues relating mixing and baking), and *bakery products* (the output of the transformation process, i.e. bakery products and hygiene). These subject links can be visually enabled or disabled with the following four options – 'no links', 'basic', 'advanced' and 'all links' – for the user to make a selection. The 'no links' option assumes that the user has sophisticated degree of the subject domain and therefore the user does not require any assistance with additional presentation of links. The 'basic links' selection presents the user with links relating to additional information about the basic concept, whereas the 'advanced links' option offers links describing more advanced information about the subject domain that the experienced user might want to obtain. Finally, the 'all links' alternative generates all subject expertise links available into the page.
- The *Language* dimension allows user to have the option to see a chosen keyword to be augmented with a selection of languages such as Latin and Spanish apart from English.
- The *Assessment preference* option provides users with a selection between the interactive and non-interactive versions of the assessment.

The ***Inquiry Linkbase*** is used to assist users in finding topics and concepts they want to know based on the domain ontology. The 'Inquiry link assistant' – one of the Inquiry tools, which will be explained in Section 6.4.3, allows the user to input a word/phrase, and if the keyword is matched with the defined ontology, the system will then automatically generate the type of relation that corresponds to that word/phrase. This automatic generation of the ontological relationship types for users to choose was designed to help users to scope down their searching strategy and also to specify the available relationship types of the searching keyword. The user can choose the type of relation, and then the link server would return the matching of related concepts of the keyword searched. The inquiry links serve as structural or associative links depending on the returning results. If the result is a concept or a topic in the domain ontology, the inquiry link then functions as a structural link. If the result is a data item then it functions as an associative link. For instance, a user searches for *'Carbohydrate'* and chooses *'tour'* as a relationship type'. Carbohydrate represents a 'concept' that is related to other concepts in the domain ontology; hence, the returning (inquiry) link serves as a structural link, which the user can use to navigate other concepts. By contrast, another user is looking for the word 'gelatinisation' with 'is' as a relationship type. Gelatinisation is a 'data item' that describes the process that starch granules absorb some water and start to form gel. This returning (inquiry) link is therefore providing an associative link, which also suggests additional links for related data items.

The ***Glossary Linkbase*** provides another set of referential links. It was implemented based on the generic linking mechanism in Microcosm. The glossary linkbase maps a keyword or phrase from the domain to explanations and concepts. A glossary tool, which will be elaborated in Section 6.4.3, allows users to highlight a keyword/phrase and generate queries that function as referential links to explanations.

The links in the IPNS application are all stored in one of the three linkbases. If no links are chosen by using the inquiry-led tools provided, users will only notice the static structural links to navigate between pages. Links within the document are dynamically augmented into existing pages depending upon users' selection in the MDL and other two linkbases.

6.4.2 Link Structures within the IPNS

The *Expertise MDL*, *Inquiry* and *Glossary linkbase* are expressed as FOHM link structures using straightforward linkbase editors. That is, a commercial spreadsheet program was used for text editing, whereby a Perl script program would transform this input into the FOHM link structure. Section 3.5 described the essential components of FOHM structures which this work has taken further and used to implement the MDL concept. *Associations* represent relationships between Data items and other Associations. *Bindings* specify connections between Associations and Data items.

References are pointers to the entirety of Data items or parts of the Data items. Finally, the *Context objects* are used to attach to any part of the structures to describe conditions on the visibility of the Data items.

Links within an MDL contain the source and destination information and can have one or many sources and/or destinations (n-ary links) depending upon the concept(s) they are representing or associating. For instance, the *Expertise MDL* holds information about keyword (source), destination, and context value (i.e. conditions on the visibility of links presentation either 'basic' or 'advanced' links, and also 'no link' or 'all links' presentation) of each link (Figure 6-7). The *Glossary linkbase* retains similar structure to the Expertise MDL except that there is no placement of context object on links to define conditions of link visibility, meaning that all glossary links (as shown in Figure 6-8) are presented to users despite their levels of expertise. However, the glossary links map the keyword/phrase from the domain either to explanation or concepts as defined in the domain ontology.

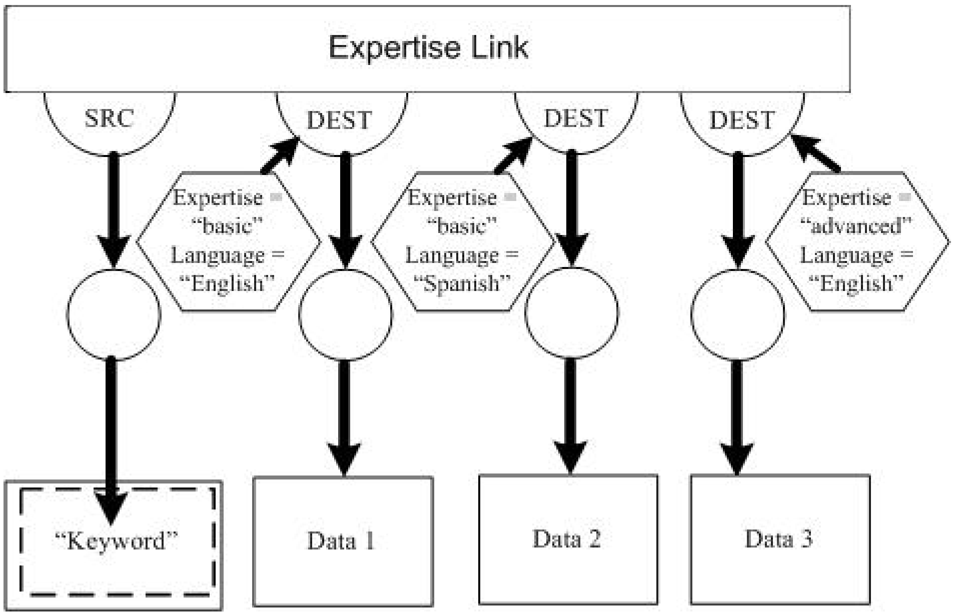


Figure 6-7: A simple FOHM Expertise MDL

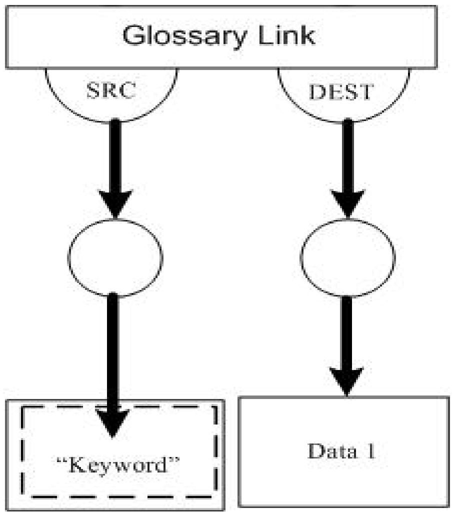


Figure 6-8: An example of FOHM Glossary link

In contrast to the other linkbases which just hold sets of links, the *Inquiry linkbase* also contains semantically structured associations to describe the author's defined domain 'ontology', as described in Section 5.6.2. A concept can represent an association or a data item. Each concept associates with other concepts by means of defined relationships, as mentioned in Table 5-1. A concept or an association in the source document can have more than one destination. Two or more different data items can be pointed at by different concepts or associations. Figure 6-9 illustrates an instance of FOHM Inquiry link.

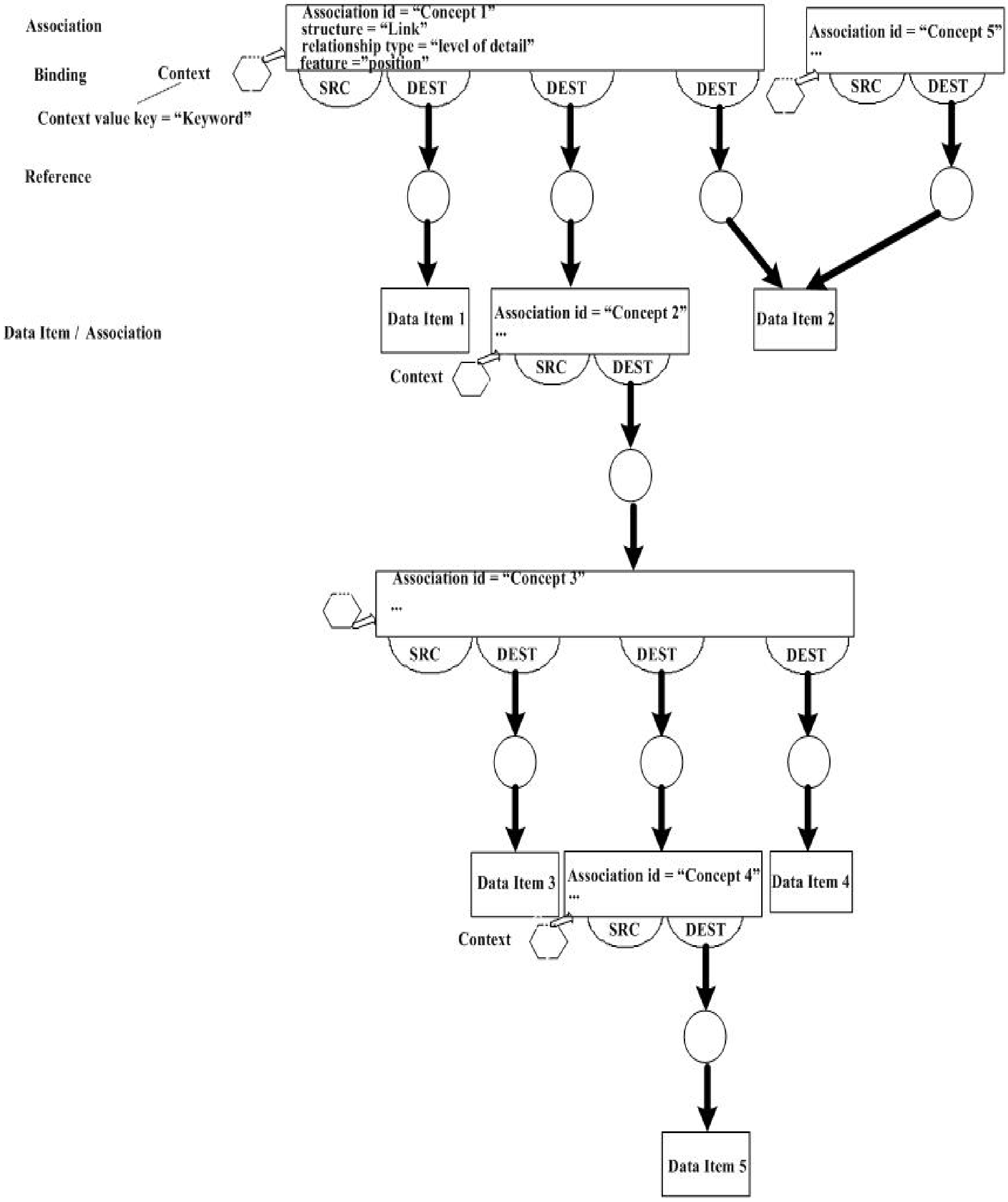


Figure 6-9: An example of FOHM Inquiry Link

6.4.3 Inquiry-led tools

As described in Section 5.6.5, the links from the MDL are presented based on the direct mapping between expertise dimensions and their contextual links in the MDL. In addition, the Inquiry and Glossary links generate links from their own linkbase. These links are supported and served by three main navigational tools, namely *Personalised Links Assistant interface*, *Inquiry Links Assistant interface* and *'Follow Links' Assistant interface*.

The *Personalised Links Assistant* interface provides a means for the user to have direct interaction with the system. The interface makes possible the insertion of the links from the *Expertise MDL* into existing pages based on user's levels of expertise and an individual user model. Users can make the *Expertise links* visible or invisible corresponding each expertise dimension. The options available for the Subject links are 'no link', 'basic', 'advanced', and 'all links' presentation. Figure 6-10 demonstrates the user interface and the corresponding links of the resulting page, as circled.

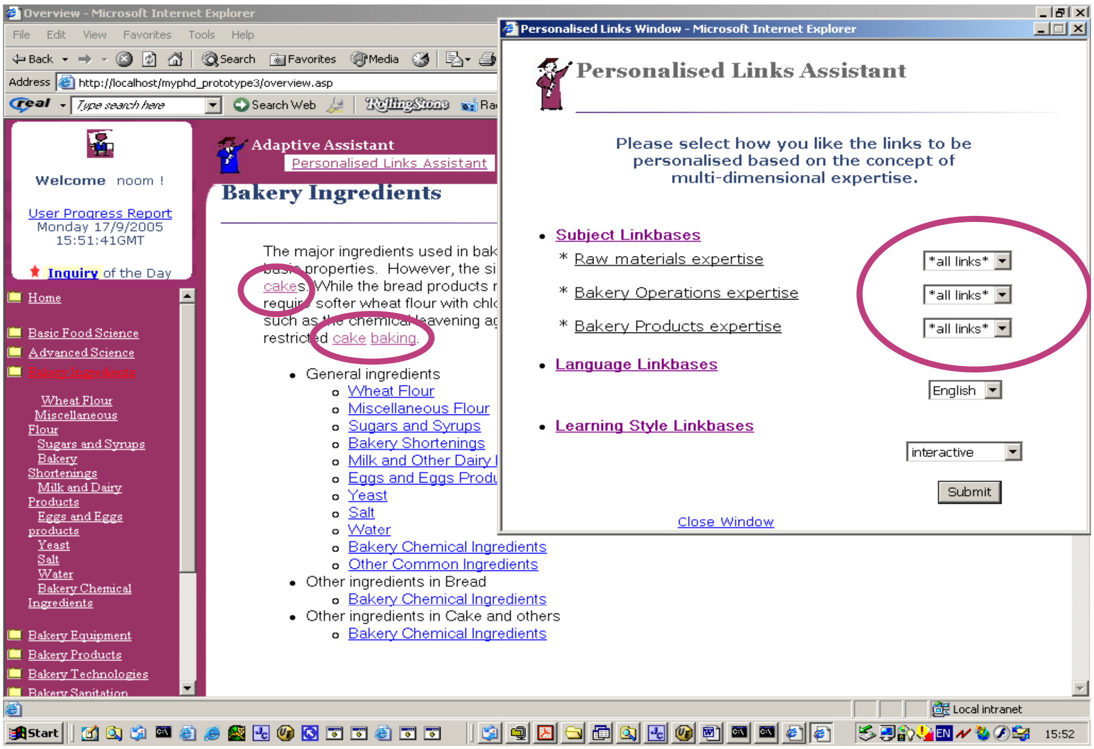


Figure 6-10: The 'Personalised Links Assistant' interface

The *Inquiry Links Assistant* interface is a keyword-search type of interface which provides the user with the facility to look for a particular topic or concept and its associated topics or concepts which were mapped semantically in a concepts relationship (ontology). These topics and concepts were expressed in FOHM and stored in the *Inquiry linkbase*. Once the user supplies a particular concept name that exists in the domain ontology, the interface will dynamically generate the relationship types corresponding to that particular concept name in the ontology for users to choose. Then, the system will return that particular concept and its associated items as a result (Figure 6-11). The resulting inquiry page, which contains the search result of the particular keyword, its concept description, selected relationship types and associative concepts, will be displayed in a new window. This new opening window was just a selected design choice to help users maintain their original navigational path and continue their main task that they have been working on. Figure 6-12 illustrates the resulting page obtained when the concept ‘cookie’ with the ‘level of details’ relationship type was entered and chosen respectively.

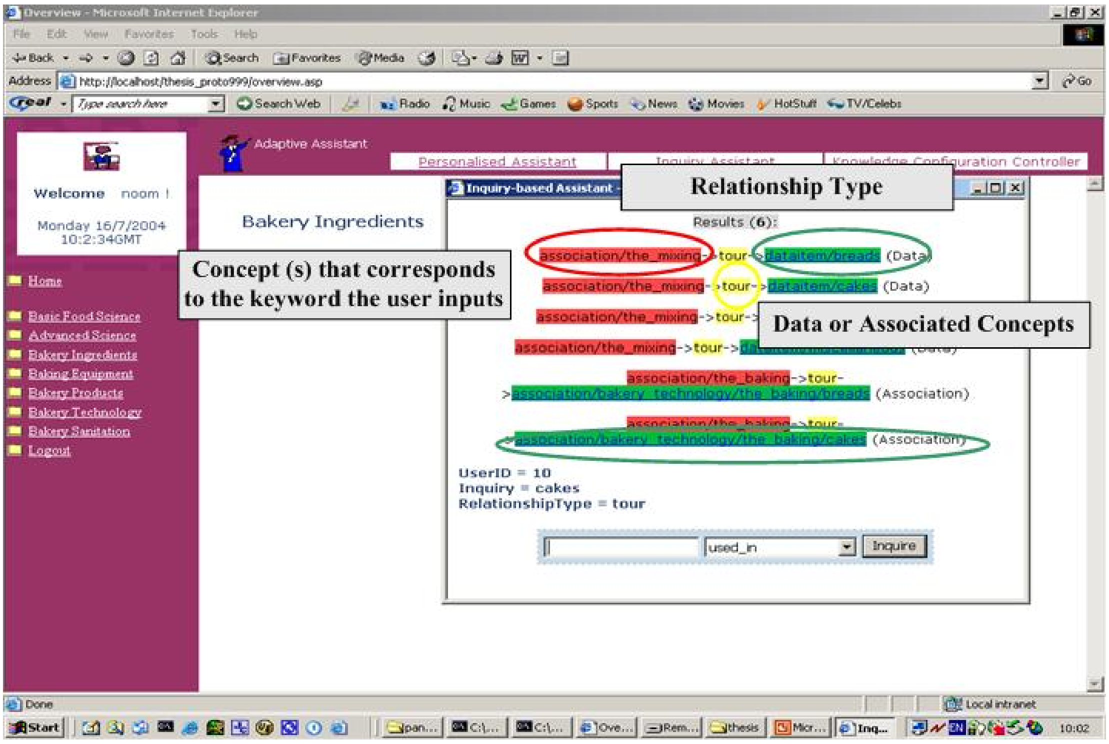


Figure 6-11: The ‘Inquiry Links Assistant’ Interface

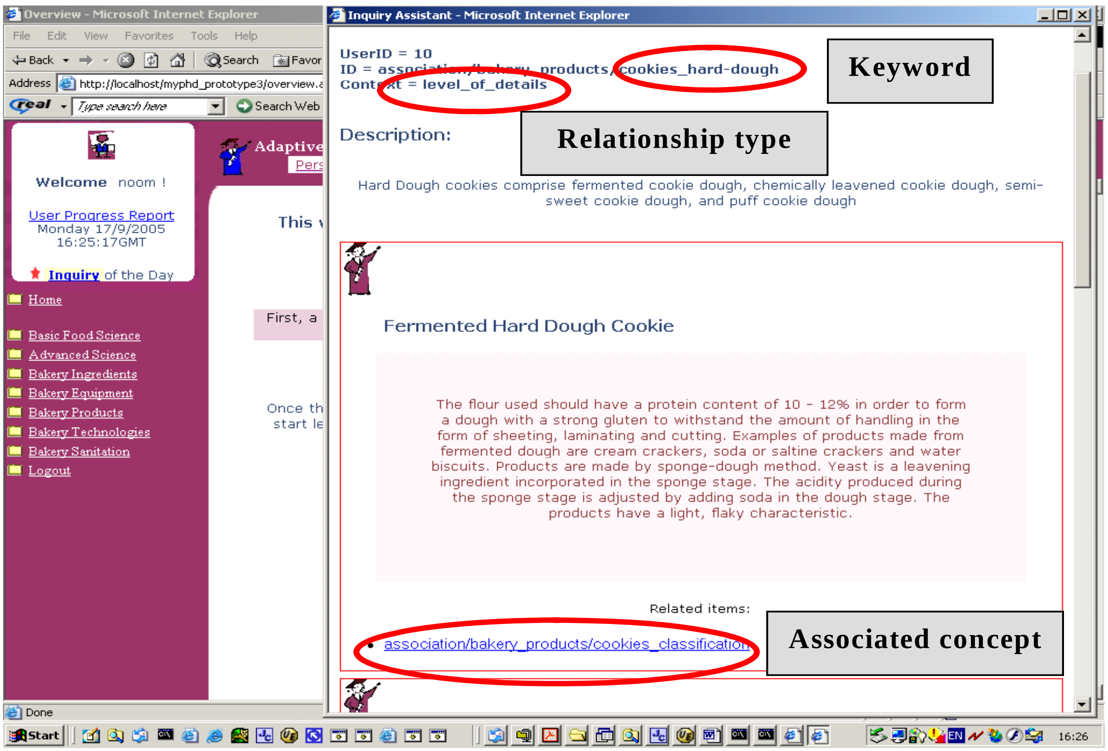


Figure 6-12: The resulting page of the ‘Inquiry Links Assistant’ interface

Finally, the last adaptation module is supplied with the implementation of the *'Follow Links' Assistant* interface. Based on the legacy of Microcosm, in which the user was enabled to create their own links to follow, this interface was designed to facilitate users in finding the links to follow. The implementation in Java Script permits this functionality. The user is presented with normal pages whereby they can highlight a keyword/phrase using the mouse device, and at the bottom of each page is embedded the 'Select Text' button (Figure 6-13), which provides the mechanism for connecting the interface with the link server. The link server then returns the finding concept and its associated items (if any) from the *Glossary linkbase* which matches with the keyword (s) sent by the submission of the 'Select Text' button and the proxy. Figure 6-14 displays the resulting page for the selection of texts the user has made, as highlighted. In this example, the only keyword that produces the result is the text 'carbohydrate'.

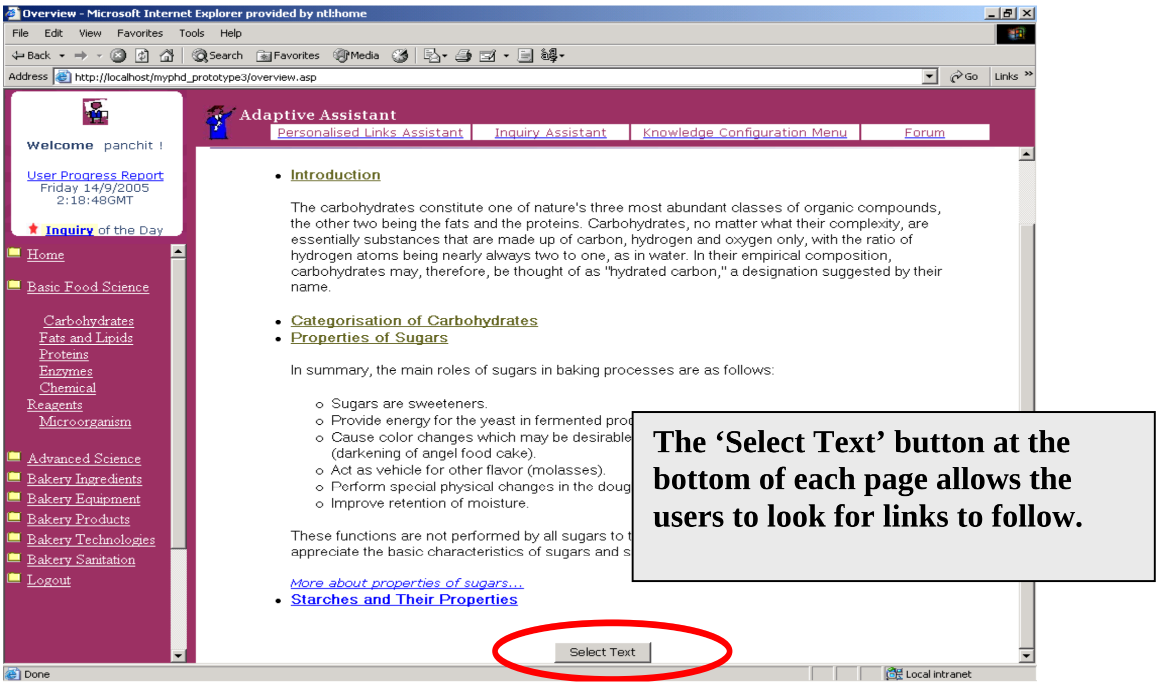


Figure 6-13: The 'Select Text' button for the Follow Links assistant interface

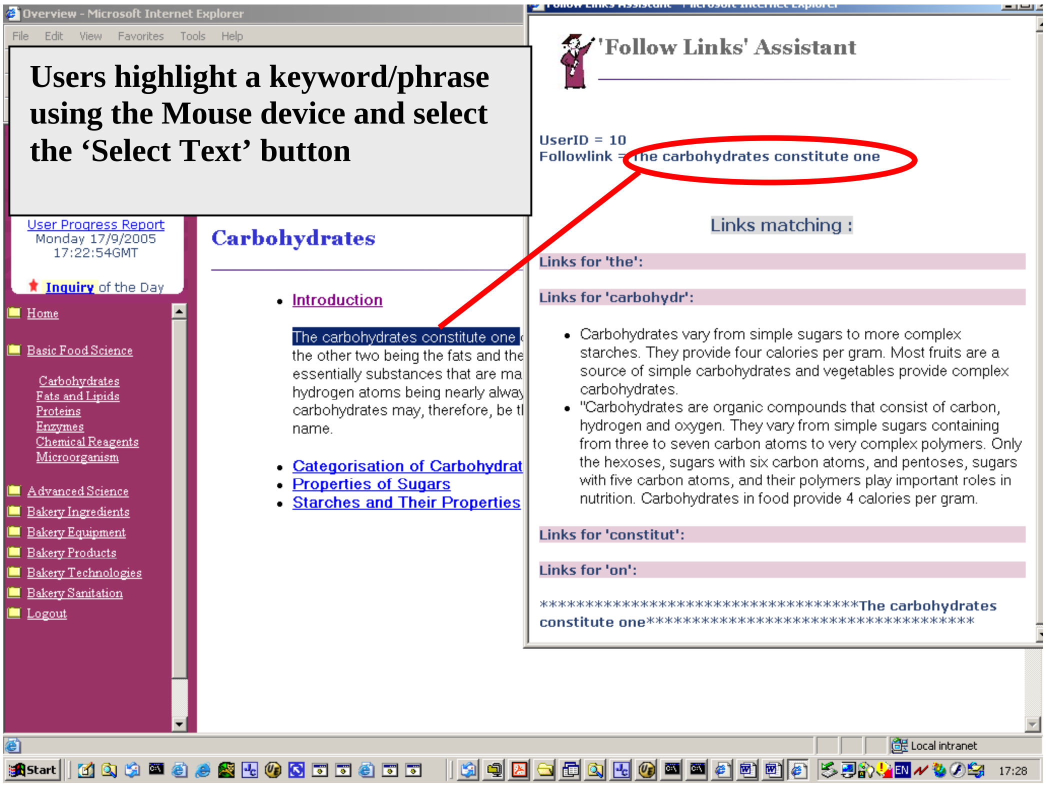


Figure 6-14: The 'Follow Links' assistant interface

All presentation of links aided by the interfaces is based on the link augmentation technique, i.e. the process of inserting supplementary links dynamically into existing Web pages. The links from the Expertise MDL and the two other linkbases are distinguished by using different colours, that is, *links from the Expertise MDL* are presented in dark pink, *links from the Inquiry linkbase* are in blue as ordinary hypertext link colour, and *links from the Glossary linkbase* are in light green colour. The colours chosen to represent different link types were based on a 'rule of thumb'.

6.4.4 Mechanism for Connecting the Personalised Components with the Link Server

The mechanism for connecting the described inquiry-led interfaces with the link server is by using the identification of individual user's hidden tags that are embedded in each navigation page. This information includes the *userID* and *expertise dimensions* and *their levels of expertise* (for the *Expertise MDL*) which is dynamically retrieved from the user model (if already stored in the database in previous transactions, otherwise, the user is explicitly required to select their levels of expertise in each dimension on their first registration with the system), and *input keyword* (for the *Inquiry linkbase*), and *highlighted keyword/phrase* (for the *Glossary linkbase*). The proxy will then locate these hidden values and communicate with Auld Linky, which in turn will finally look at the sending query and provide the context culling system and obtain the links matching the above context in the Expertise MDL and linkbases for a given user.

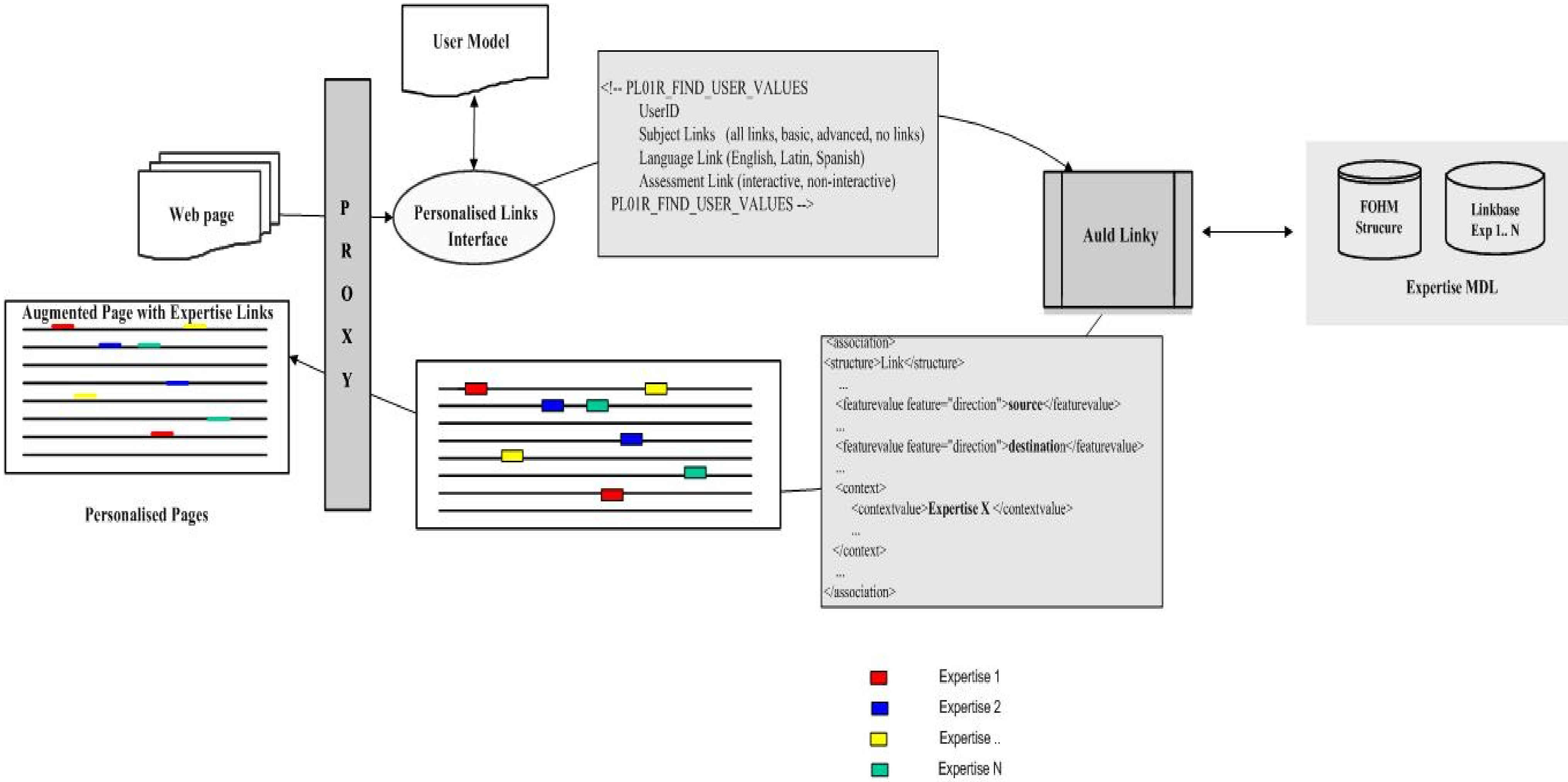


Figure 6-15: The mechanism for connecting the ‘Personalised Links Assistant’ interface with Auld Linky and the Expertise MDL

Figure 6-15 shows the connection of the *Personalised Links Assistant* interface and the *Expertise MDL*. Based on the previous work on the personalised Thai Cookery site, the connection between the personalised interface and the link server is similarly performed by using the identification of users' hidden tags which are embedded in each page. However, there have been significant modifications regarding users' categorisation and links classification. Instead of designating users with the stereotype based on their pre-test performance, an individual user model was simply built based on their own selection of expertise dimensions and their expertise levels. The users can select their own links presentation and change it to suit their preference at any time. The user is presented with three different expertise dimensions which are stored in a single contextual linkbase (MDL) – *Subject*, *Language*, and *Assessment preference*, as previously documented. The hidden tag and its values for the *Expertise MDL* for a user now contains the UserID, the values of the Subject links, Language link and Assessment link.

The *Subject links* which have an other three sub-dimensions, *raw materials*, *bakery operations* and *bakery products* all are equipped with four further options – 'no link', 'basic', 'advanced' and 'all links'. These options are associated with values, as displayed in Table 6-1, which will be used to interact with the database.

"all links"	1
"basic"	25
"advanced"	75
"no links"	100

Table 6-1: Mapping between the score of expertise levels and the context in the Expertise MDL

The proxy in turn locates and returns the hash table with these string hidden values which will be used to communicate with Auld Linky. Finally, Auld Linky will obtain links matching the above (string) context in the linkbase: *raw materials links*, *bakery operations links*, *bakery products links* and *language link* in the Expertise MDL and perform the culling process. The remaining matching expertise links will then be augmented into an existing page, based on the hidden values of an individual user model with relation to user's expertise dimensions and their levels of expertise.

6.5 Adaptive Techniques Used in IPNS

In addition to the adaptation provided by the OH link augmentation technique, IPNS also employed the AH techniques – *adaptive presentation* (content level) and *adaptive navigational support* (link level).

The adaptive presentation was implemented with the '*conditional fragments*' technique (De Bra and Calvi, 1998a), that is, a means to include or exclude fragments of texts, paragraphs, or pages using if-else statements which enabled decisions to be made on what contents or links are to be displayed to the user based on their user models. Figure 6-16 demonstrates how the conditional fragments were implemented, similar to the AHA! approach (De Bra and Calvi, 1998a).

```
<% // to check number of lessons visited %>
<% If noOfvisitedLessons1 > (count1/2) Then %>
        <% // display one thing %>
<% elseif noOfvisitedLessons2 > (count2/2) %>
    <% // display another thing %>
<% else %>
    <% // display something else %>
<% end if %>
```

Figure 6-16: Adaptive presentation in IPNS

The adaptive navigational support was put into practice by the use of techniques as follows.

Link hiding: a technique to make the links look neutral but still active until the conditions are met, when the links will become visible. For example, in IPNS, some heading such as Personalised assessment, although it is functional, can only become visible to a user when the user has visited some other basic concepts.

Link annotation: a means to present to the user the supplementation of links with different colours, fonts, etc. to reflect the current state of the annotated links. In addition, the links from the *Inquiry Linkbase* also implemented the use of the link colour annotation technique. This distinction in colour will be presented and dependent on different relationship types of associations or concepts. Figure 6-17 demonstrates the difference in the colour of concepts outside table border. In the example, the colour of the outside border appears 'blue'; this means that the searching concept 'cookie', the user has supplied in the 'keyword-search' inquiry tool, is an 'association' with relationship type 'tour' in the link structure .

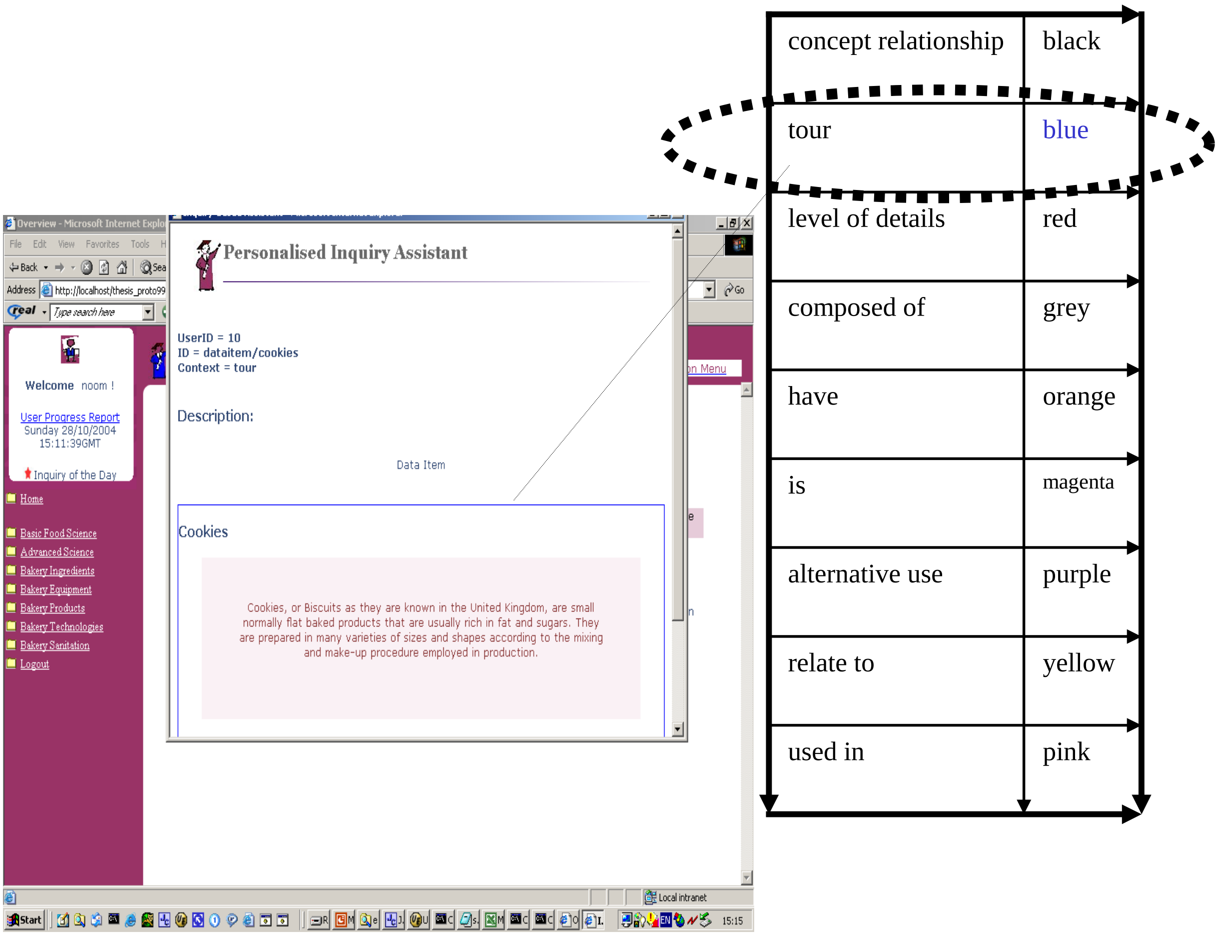


Figure 6-17: Link annotation based on the relationship types of associations or concepts

Link augmentation: the key method of this PhD work – a technique to insert additional links or related information to an existing page, as previously described. Link augmentation is not listed in the taxonomy of adaptive techniques proposed by Brusilovsky (Brusilovsky, 2001), although the technique has been employed in other AH systems (Maglio and Farrell, 2000; Bailey and Hall, 2000; Bailey *et al.*, 2002; Bailey, 2003; Maneewattana *et al.*, 2005).

6.6 Other Personalised Features in IPNS

This section presents other personalised features applied in the IPNS. Although these features were not directly related to the research objectives, they were implemented to offer additional functions.

In addition to the IPNS providing the user with adaptation (i.e. personalisation of links) based on the *Expertise MDL*, IPNS also keeps records of *user's browsing history*. With regard to the Expertise MDL, the individual user's expertise dimensions and their levels of expertise have gained from the initial setting by the user and the user then later makes modifications to these expertise levels to suit their preference. On the other hand, the personal browsing history is obtained from pages navigated by users.

6.6.1 Personalised Site Map

The site map in IPNS presents the number of documents in each topic presented on the site. The personalisation is based on individual *user's browsing history*. As can be seen in Figure 6-18, this personalised site map serves as a navigational support to allow users to have an overview of the subject domain whereby the user can see pages under each topic which the user has already viewed, or not yet visited.

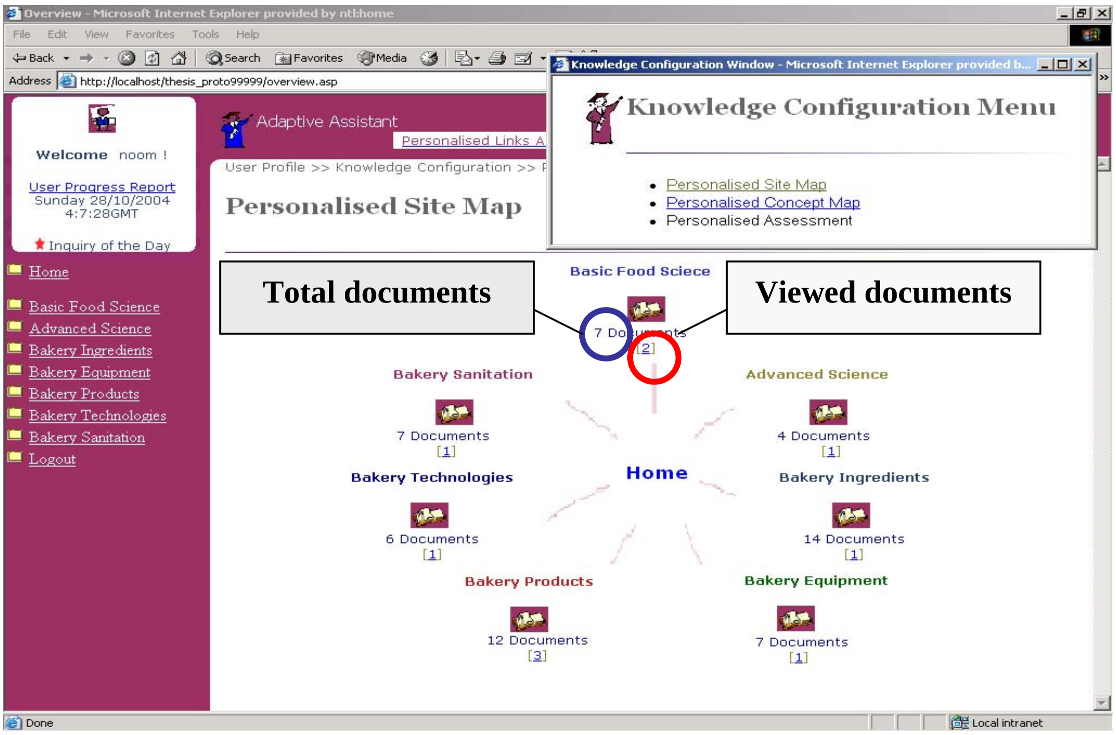


Figure 6-18: A screen shot of the personalised site map of IPNS

6.6.2 Personalised Assessment

The personalised assessment in IPNS is individually presented to users based on a selection of the assessment preference the users choose, that is, *interactive* and *non-interactive* version. These exercieses were designed to assist users in monitoring their navigational completion.The interactive assessment uses Flash MX 2004 technology to allow users to interact with objects in the exercise by dragging and dropping around the objects into designated areas. If the user places an object into its assigned area correctly, the user will achieve a point demonstrated by a 'tick' mark (see Figures 6-19, 6-20, 6-21). The point will be collected and added up, and the user will see their total score once the user has completed each exercise. In addition to the interaction version, the non-interactive exercise is in the form of a multiple-choice exercise.

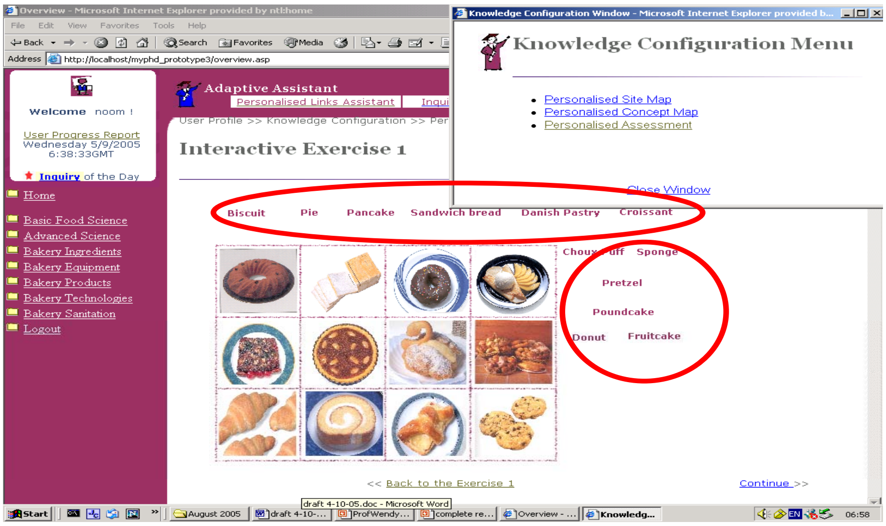


Figure 6-19: The 'interactive' version of the personalised assessment

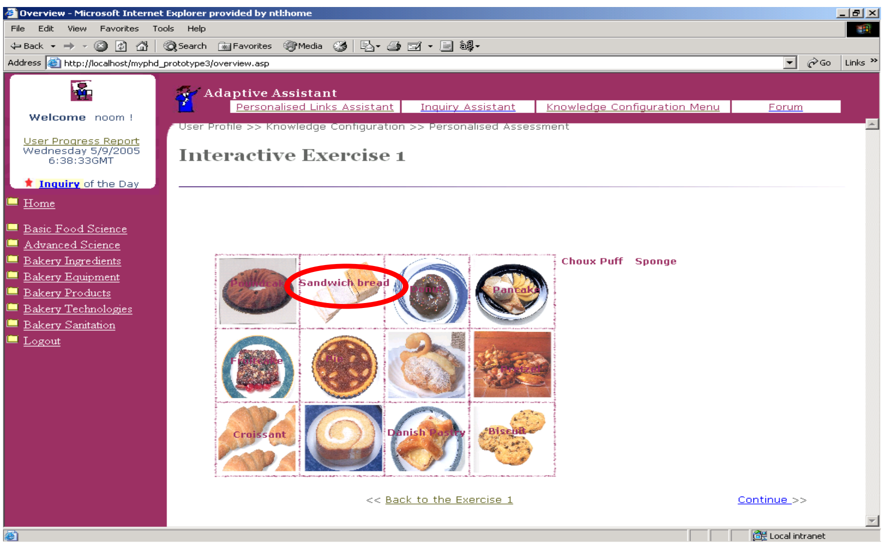


Figure 6-20: The drag and drop interface using Flash MX 2004

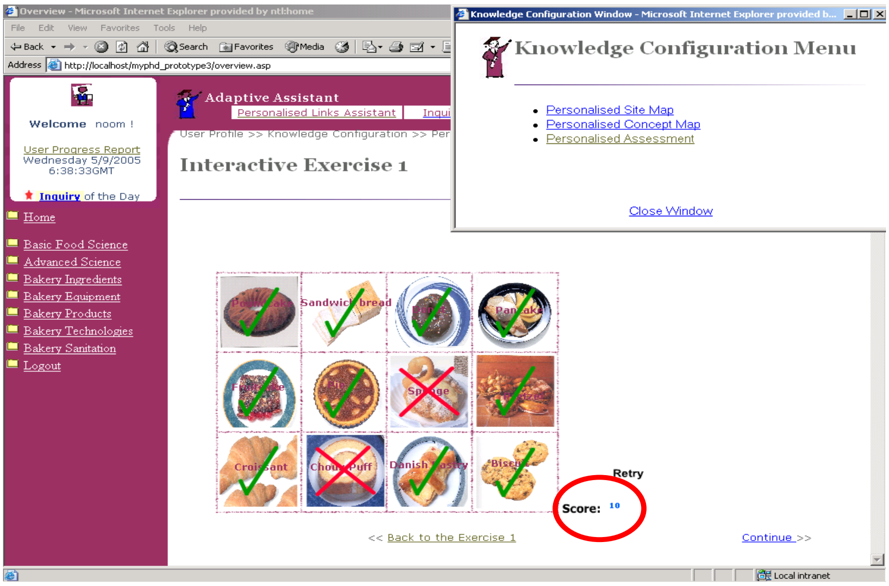


Figure 6-21: The scoring page of the interactive exercise

6.6.3 Personalised User Report

The personalised user report encapsulates the user's profile featuring the information such as user ID, user's name, email and date of registration (Figure 6-22). It also provides a record of user's activity such as pages visited, exercises attempted and the scores, and current inquiry task the user is recommended to perform.

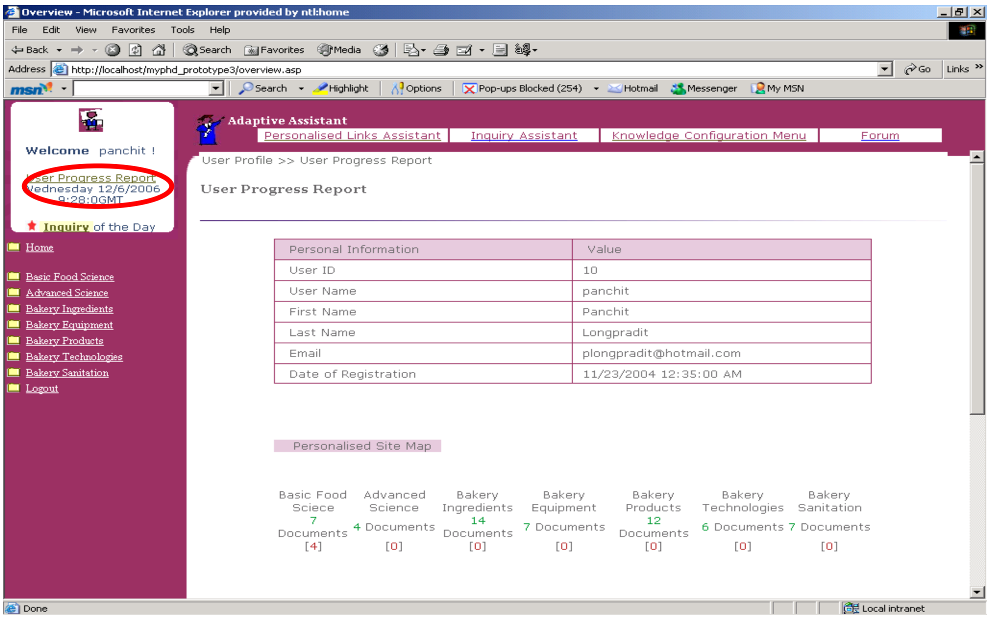


Figure 6-22: The personalised user progress

6.6.4 *Personalised Inquiry of the Day*

The personalised inquiry of the day informs the user of their current status, that is, a suggestion to attempt one of the inquiry tasks (Figure 6-23). The inquiry will be assigned dependent on the current status of the users from their browsing history and performance from the assessment. This personalised message can be viewed as another means to provide feedback to users on their current stage of navigation of the subject domain.

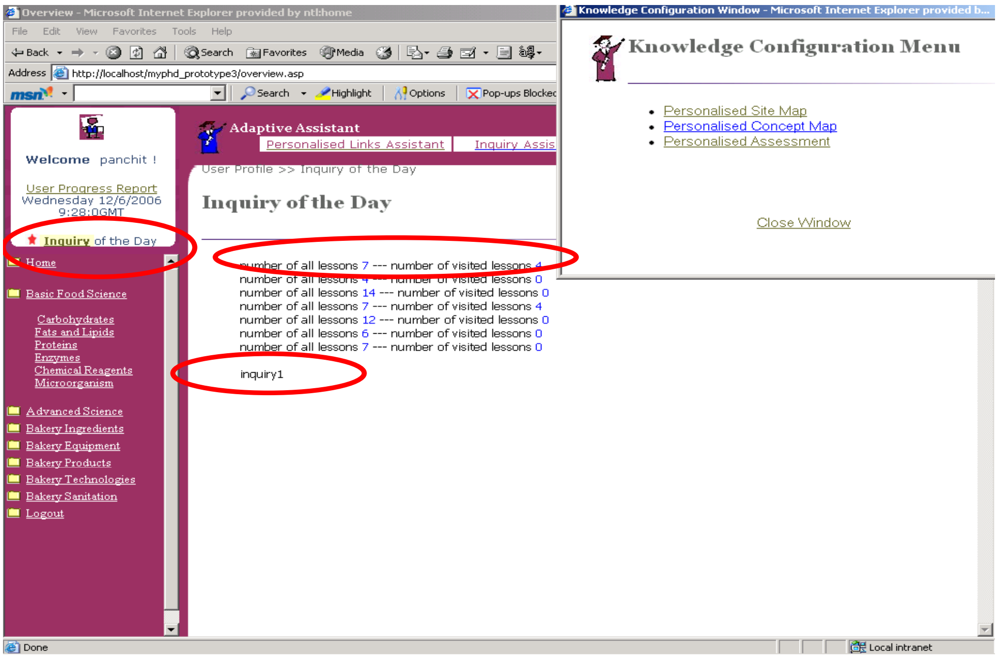


Figure 6-23: The personalised inquiry of the day

6.7 Summary

This chapter has presented the integration of the concept of a multi-dimensional linkbase (MDL) and the inquiry-led navigation system (INS), which resulted in the development of a Web-based inquiry-led personalised navigation system (IPNS) prototype. The chapter began with the Web site description, system architecture, and its conceptual overview. Then, the chapter touched upon the system implementation concerning how the concept of a multi-dimensional linkbase was put into practice where the emphasis was placed on the issues such as MDL implementation, link structures within the IPNS MDL(s), inquiry-led tools and mechanisms which make possible the personalisation.

The concept of a multi-dimensional linkbase is about the representation of links visibility in different contextual dimensions. In the prototype system, IPNS, the concept of MDL was applied to the Expertise MDL. The Expertise MDL inserts additional links into a page for supplementary explanation based on user's expertise dimensions and their levels. The Expertise MDL represents three examples of dimensions of expertise – Subject, Language and Assessment. The Subject links in particular have sub-dimensions as raw materials, bakery operations and bakery products. In addition, two more linkbases, Inquiry and Glossary linkbase, were also introduced to provide the user with more navigational functions. The Inquiry linkbase provides links corresponding to a user's search for a particular topic of interest, and the Glossary linkbase offers glossary links on demand. Both linkbases can also be further developed to support MDL. Following this, the description about other adaptive features implemented in IPNS are also documented.

This chapter has demonstrated the novelty of the concept of a multi-dimensional linkbase, and that the MDL concept can be put into practice. The work in the next chapter will present a formal evaluation study of the MDL concept applied and implemented in this chapter to prove that its concept and implementation is applicable and meaningful for users with different levels of expertise and background.

Chapter 7 Evaluation

7.1 Introduction

This work has proposed additional functionality to the link augmentation technique using a multi-dimensional linkbase for developing a Web-based personalised navigation system, the IPNS. As previously described, the two main research objectives of the work proposed are to present a new application of the link augmentation technique (i.e. to solve the link overload problems and to present a different view of representing a linkbase to support link augmentation) and to facilitate user control over a personalised system. The evaluation chapters will therefore reflect these objectives.

This chapter begins with the general background regarding evaluation, evaluation of human-computer interaction and evaluation of hypermedia systems. Then, an evaluation approach specifically for IPNS is presented, using heuristic and empirical evaluation techniques, the results of which will be documented in the next chapter.

7.2 Background

Evaluation is defined as the process of examining the product, system components, or design, to determine its usability, functionality and acceptability (Dix *et al.*, 2004), which is measured in terms of a number of criteria (Preece *et al.*, 2002), essentially for any software development project. It is carried out by designing an evaluation plan – specifying goals, decomposing goals into evaluation questions, setting criteria for deciding questions, identifying data required to answer questions, selecting methods for collecting data and analysing data (Sasee, 2005b); conducting experiments either in the experimental lab or in the field; collecting data that can be qualitative and/or quantitative, or subjective and/or objective; analysing and interpreting the data; and reporting and drawing conclusions based upon the established hypothesis. Typically, evaluation can be undertaken either with the user's participation (user evaluation), or with the absence of the user's involvement (system evaluation). On the one hand, system evaluation places an emphasis on comparison of the presented system with establised criteria proposed by other researchers or other related systems, i.e. systems which have similar features or goals. On the other hand, user evaluation is user-centric, that is, it engages users to appraise the system or system components. The user is presented with qualitative and/or quantitative data collecting methods and techniques, data from all of which will be analysed and conclusions will be drawn based on the findings and conjectured hypothesis.

7.3 Human-Computer Interaction (HCI) Evaluation

In HCI, one of the primary system assessments is its usability. Usability is about the effective interaction between people and the system. ISO/DIS 9241-11 defines usability as *the extent to which a system can be used by specified users to achieve particular goals that are measured in terms of effectiveness, efficiency and user satisfaction in a specific context of use* (ISO/DIS 9241-11). *Effectiveness* implies accuracy and completeness of the system which enables users to achieve specified goals. *Efficiency* is sometimes paired with the effectiveness to form the term 'performance'; it extends the effectiveness in terms of the amount of effort users put in, or the relation of level of effectiveness achieved to the expenditure of resources such as effort, time, materials and cost. *Satisfaction* is exhibited by the comfort and positive attitudes users perceive from using the system. Furthermore, ISO/DIS 9241-11 also identifies that, when measuring usability, the following information is required:

- a description of the intended goals;
- a description of the components of the context of use (users, tasks, equipment, environments);
- target or actual values of effectiveness, efficiency, and satisfaction for the intended contexts.

HCI evaluation is a review of usability in a systematic way (Jacobs, 1998) to improve features within an interface and its supporting material (Preece *et al.*, 1993). Nielsen (1994a) used the generic term 'usability inspection' to describe a set of methods aimed at finding usability problems in designs. Similarly, Whitefield *et al*. (1991) described usability evaluation as an assesessment of the conformity between a developed system's performance and the desired performance. Typically, HCI evaluation is concerned with gathering the data about the usability of a design or a developed product from a chosen group of users performing a certain activity (Preece *et al.,* 2002). Preece *et al.* (2002) also underlined the four reasons to accomplish evaluations as follows.

- To understand the real world, that is, to find out how a design can fit the work environment better;
- To compare designs;
- To engineer towards a target, that is, to make sure the product is delivering at least as good as one offered by competitors or older versions;
- To check whether the design conforms to the standard.

There are generally two modes of evaluation, namely *formative* and *summative evaluation*. Each has a different objective and is undertaken at different phases in the software development life cycle. Theoretically, a complete evaluation requires both forms in different proportions (Wills, 2005a). *Formative evaluation* is used to refine the design phase, and to elicit how users find out about the system and what problems the users experience when interacting with the system. *Summative evaluation* concerns the improvement of system usability and performance once the product has been produced and is operating.

Furthermore, evaluation can also be divided into *analytical* and *empirical*. The emphasis of *analytical evaluation* is placed upon predictions of sytem performance (Sasse, 2005a) and usability problems (Rauterberg, 2005) without the presence of real end-users. Alternatively, *empirical evaluation* is ‘observation-based evaluation’ in which evaluators observe users’ interaction with the system, and is also ‘user report-based evaluation’ where users are requested to present information about the usage of a system (Sasse, 2005a).

The choice of evaluation is very much dependent on what is to be evaluated, so are the techniques. Sometimes it is essential to apply more than one technique in an evaluation study. Appendix D provides a summary of HCI evaluation methods and techniques.

7.4 Evaluation of Hypermedia and Adaptive Hypermedia Applications

This section presents a fundamental background of methods and techniques of evaluation of hypermedia and adaptive hypermedia applications.

7.4.1 Evaluation of Hypermedia Applications

Generally, HCI evaluation methods and techniques can be used to assess the usability of hypermedia systems and applications. To name just a few, interviews, questionnaires, session logging, and observation are suggested (Nielsen, 1990b). In addition, the cognitive walkthrough method is also applied with the emphasis on all possible routes the user can take while interacting with the system (Newman and Lamning, 1995). However, the fact that users subjectively navigate through information space is particular to hypertext problems (Hothi, 2001), such as where we are now and where we can go next and also problems with keeping the tracks visited by users (Nielsen, 1990a). This complexity introduces the cognitive overload problem, and results in a need for different criteria for evaluations (Wright, 1991). In addition, Hothi (2001) reported that the usability of a hypertext application relies not only on the user-friendliness of the interface, but also on a combination of issues regarding the usability of a hypertext system such as a hypermedia system engine (presentation and navigational support) and the contents and structure of the information space.

Nielsen (1990b) presented five usability criteria for evaluating hypertext usability in his 'discounted usability engineering' approach, namely, *easy to learn*, *efficient to use*, *easy to remember*, *few errors*, and *pleasant to use*. *Discounted usability engineering* (Nielsen, 1993; Nielsen, 1994a; Nielsen and Mack, 1994) is a cheap, fast and easy-to-use usability method which proposes to overcome the problem with some usability methods that are expensive, intimidating, difficult and time consuming to use. This engineering approach is centred on *scenarios or prototyping*, *simplified thinking aloud*, and *heuristic evaluation*.

Heuristic evaluation (Nielsen and Molich, 1990; Nielsen, 1992; Nielsen and Mack, 1994) was defined as *a usability engineering method for finding usability problems in a user interface design so that they can be attended to as part of an iterative design process.* Heuristic evaluation requires a small group of expert evaluators who will examine the interface and assess its conformity with usability criteria (i.e. the “heuristics”). Nielsen (1994b) revised usability “heuristics”, as follows: *visibility of system status*, *match between system and the real world*, *user control and freedom*, *consistency and standards*, *error prevention*, *recognition rather than recall*, *flexibility and efficiency of use*, *aesthetic and minimalist design*, *help users recognise, diagnose, and recover from errors*, and *help and documentation.*

Garzotto and Paolini (1997) introduced a framework for systematic evaluation of hypermedia (SUE), in which they took the following usability criteria into consideration:

- *Accessibility* (or *Retrievability* in Wills (2000) – to determine how effortless it is for a user to find relevant information;
- *Orientation* – to find out the ability of the user in knowing his/her navigational paths and locations;
- *Reuse* – the reusability of same objects and operations in different contexts and purposes;
- *Richness* – to assess if the system provides enough pieces of information and means to attain them;
- *Self-evidence* – to measure if the user is noticeable to the meaning or purposes of what is being presented to him or her;
- *Predictability* – to gauge the user’s ability to expect the meaning of similar structures or operations seen previously in similar but different situations;
- *Consistency* – to ascertain that similar and different elements are treated accordingly to their own fashion.

Other evaluation criteria involve the software usability measurement inventory (SUMI), a toolset for usability assessment developed on the ‘Metrics for Usability Standards in Computing’ project at University College, Cork, Ireland (Kirakowski and Corbett, 1993; Wills, 2000), which are as follows:

- *affect* (users’ emotional feelings toward the usage of software),
- *efficiency* (the degree to which the software completes the tasks in specified time),
- *learnability* (the degree to which the application is straightforward for users to become familiar with),
- *helpfulness* (the degree to which the software assists the user in a situation),

- *control* (the degree that the application responds to user inputs in a consistent way).

Additionally, Wills (2000) appended another two measurements for evaluating industrial hypermedia, namely:

- *navigation* (the ability that users can move around the hyperdocument) and
- *comprehension* (the extent to which users can be familiar with the interaction with the system).

Software metrics are another criterion a number of researchers have focussed their work on. It is referred to as the numerical measurement of some properties of a software product or processes of software development (Wills, 2000). Babiker *et al*. (1991) proposed a metric for evaluating hypertext systems usability based on three issues:

- *access and navigation* (how easy it is for users to navigate within hypertext documents),
- *orientation* (how well users know where they are and where they have visited),
- *user interaction* (how simply the user can interact with the hypertext system),

which they claimed could provide an effective means to identify problems associated with the system and also as a basis for comparison between different hypertext systems. Furthermore, Basili *et al*. (1994) suggested the Goal-Question-Metrics (GOM) approach. To apply the GOM concept, the overall goals of measurement need to be firstly specified; then from each goal, a set of questions, which need to be answered to determine if the goal is going to be achieved, are derived; and finally, each question is analysed in terms of what measurements are required to answer to each question (Fenton and Pfleeger, 1997).

7.4.2 Evaluation of Adaptive Hypermedia

It is believed that this evaluation chapter will not be complete without mentioning evaluation of adaptive hypermedia. However, since evaluating AH systems is beyond the scope of this work, this section gives a brief overview of literature relating to evaluation of AH systems. Generally, conventional HCI evaluation methods and techniques such as users' opinions (questionnaires and interviews), users'observations, experiments, as well as predictive evaluation (heuristic evaluation and expert reviewing), still proved useful. However, the main difference between evaluation of interfaces, hypermedia and adaptive hypermedia lies in the nature of their complexity and functionality (Hothi, 2001), in particular the comparisons of the systems with and without adaptivity and measurements of the levels of adaptivity provided (Höök, 1997).

With regard to what to measure when evaluating the adaptivity, Weibelzahl (2003) presented a comprehensive list of criteria that have been applied in evaluation studies of adaptive systems such as *accuracy*, *precision* and *recall* (particularly for information retrieval and filtering systems); *learning gain* (adaptive learning systems); *amount of requested materials*; *duration of interaction*; *number of navigation steps*; *task success*; *usability questionnaires*; *user satisfaction*; etc.

Furthermore, Weibelzahl (2005) further described several evaluation frameworks focussing on the notion that evaluation of adaptive systems should not consider adaptation as a single process but rather separate it into different components, where each part needs to be evaluated distinctively. The concept of breaking down adaptation for evaluation purposes was initiated by Totterdell and Boyle (1990). Brusilovsky *et al.* (2001) proposed the layered evaluation approach whereby evaluation of the *interaction assessment layer* and the *adaptation decision-making layer* are independently conducted. Other ideas are centred on this pioneering approach. For instance, Magoulus *et al.* (2003) modified heuristic evaluation and integrated it into the layered evaluation. Paramythis and Weibelzahl (2005) decomposed the adaptation process and evaluated the system in five different stages: *collect input data*, *interpret data*, *model the current stage of the world*, *decide upon adaptation*, and *apply adaptation*.

Until recently, many studies pinpointed that evaluation of adaptive hypermedia has been so limited (Eklund and Brusilovsky, 1998; Masthoff, 2002) or problematic (Weibelzahl, 2005). Extensive studies about evaluating adaptive systems can be found in Weibelzahl (2005) and Gena (2005).

7.5 Evaluation Approach to IPNS

IPNS has stemmed from two areas of research: open hypermedia and adaptive hypermedia. As previously described, the objectives of the work proposed were to present a new application of the link augmentation technique (i.e. to solve the link overload problems and to present a different view of representing a linkbase to support link augmentation), and to allow users control over personalisation. Weinreich *et al.* (2001) pointed that the availability of many link types is only helpful if the user can distinguish between their differences. It would be needless to provide users with a vast array of links which cause users navigational overload and none of the links makes any sense.

As demonstrated in early chapters, the concept of a multi-dimensional linkbase and its implementation have confirmed that the MDL concept has provided a new additional functionality to support the link augmentation technique by presenting a different view of representing a linkbase for personalisation of links. The main emphasis of the evaluation approach to IPNS was therefore to find the evidence to support that user adaptation provided by the MDL concept allowed users to have control over personalisation by enabling users to see the working behaviours of the adaptive system. Through a better understanding of the adaptive behaviours, the users can make adaptation better work for them and hence this user-adaptation approach (or user controlled adaptation) can help to reduce the link overload problem caused by the link augmentation technique.

Based on the above reflection, user's control over personalisation (or user controlled adaptation) formed an underlying principle for evaluation of IPNS. The evaluation was divided into two separate rationales. Firstly, the goal was to measure the applicability of the user-controlled adaptation provided by the MDL concept as applied to the development of IPNS; and secondly, to find out the usefulness of the user-controlled adaptation provided by the MDL concept as applied to the prototype. The results of the evaluation have provided some evidence for the following hypotheses:

- The user-controlled adaptation provided by the MDL concept is applicable,
- The user-controlled adaptation provided by the MDL concept is useful for users.

Usability was chosen as the evaluation criteria (*effectiveness*, *efficiency*, and *user satisfaction*). IPNS is more a personalised or adaptable system than an adaptive system. Although the two terms – adaptation and personalisation, are used interchangeably in this thesis, there was no presentation of an inference mechanism to the users for adaptivity. Rather, the IPNS prototype provides users with the tools (functionality) that make possible changes in the system's behaviours or characteristics (adaptability), which in this case presentation and personalisation of links, in accordance with users' preferences and background. As a matter of fact, the only research interest for this evaluation, adapted Dix *et al.* (2004), was to ensure that the user adaptation provided by the MDL concept was applied rightly and the prototype developed behaved as expected and met its requirements. However, general usability testing of interfaces is also out of the scope of this evaluation study.

7.5.1 Description of Subjects

Yamada *et al.* (1995) noted that evaluation of a hypermedia application is important, and it is essential that it is tested with appropriate end users and within the environment where the developed system is going to be used. Dix *et al*. (1998) also emphasised that the success of any evaluation experiment relied significantly on the choice of subjects. This is because the validity of the evaluation results can provide a constructive design solution and be used as the future reference on design decisions.

In IPNS, the choice of subjects taking part in the experiment was divided into two main groups. The first group was a set of six computer science postgraduate students and two researchers, and one IT related professional, regarded as 'expert evaluators', assigned to conduct *a heuristic evaluation* to report any strengths and weaknesses and the applicability of the user-controlled adaptation provided by the MDL concept. The second group, a set of twenty four subjects, was to perform the second rationale of the evaluation, that is, to find out the usefulness of the user adaptation provided by the MDL concept (*an empirical evaluation* or *a users evaluation*). Table 7-1 depicts the distribution of the subjects in the experiment.

Group	Gender			Background	
	Male	Female	Total	Computer Science	Non-computer Science
Heuristic Evaluation	4	5	9	9	0
Empirical Evaluation	8	16	24	6	18

Table 7-1: The distribution of subjects

Empirical Evaluation	Computer Usage			
	For Study/Work		For Internet/Email	
	None	Regularly	None	Regularly
Users	0	15	0	9

Table 7-2: The distribution of subjects for the 'users evaluation' in terms of computer usage

As can be seen in Table 7-1, in terms of gender distribution, there were four males and five females in the 'heuristic evaluation' group, and eight males and sixteen females in the 'users evaluation' group. With respect to background, expert evaluators in the heuristic evaluation group were all computer science postgraduates and researchers, whereas subjects for the user evaluation group were randomly sampled: six computer science postgraduate students, thirteen other science related postgraduates, and five postgraduates from other disciplines. The age group of the 'users evaluation' group ranged from 23-41 years. Concerning the computer usage (Table 7-2), fifteen subjects regularly use computer for work or study (usually, often, always), and nine subjects frequently use computer for internet/emails (often to always). Appendix B (II: page 193) exhibits the pre-evaluation questionnaire.

7.5.2 Defining Evaluation Tasks and Evaluation Methods

The definition of tasks in this thesis can be divided into two: one is *heuristic evaluation*, and another is *empirical evaluation* or *users' evaluation*.

First, the **heuristic evaluation** was employed to provide the criteria or 'heuristics' for examining *the applicability of the user-controlled adaptation provided by the MDL*, to identify some existing problems about the way the concept was applied (not to verify the non-existence problems), and to offer a quick result with low cost and the resolution of problems. This work used the original usability heuristics by Nielsen (1993) – *Flexibility and Efficiency of Use*; *Easy to Comprehend*; *Easy to Remember*; *Pleasant to Use; User Control and Freedom; Few Errors; Consistency; Aesthetic and Minimalist Design*; and *Match between the System and the Real World*. However, the *Help and Documentation* heuristic was not included as the system was a protoype developed to prove the application of the user adaptation provided by the MDL concept, that is, it was not yet developed as a full working system; hence the help and documentation functionality was not implemented in this current version. Table 7-3 presents a complete list of heuristics and their description. The actual heuristic form can be found in Appendix A (II: page 188) .

Heuristic	Description
Flexibility and Efficiency of Use	The system should be able to deliver its functionality (i.e. the presented links are rightly functional and acceptable) either to experienced or inexperienced users and allow users to perform their task.
Easy to Comprehend	The user should find it easy to understand the interaction with the system i.e. interacting with the links interfaces is easy to understand.
Easy to Remember	The user should not have to remember instructions in order to interact with the system.
Pleasant to Use	The system should provide a user-friendly interface and the user should enjoy interacting with the system.
User Control and Freedom	The user should be able to choose the system functions (i.e. link presentations and personalisation) and have control and freedom in interacting with the system.
Few Errors	The system should be error free or generate few errors i.e. the system should deliver links rightly according to its function and interface.
Consistency	The use of language and format of the system (i.e. the presenting links) should be consistent.
Aesthetic and Minimalist Design	The system should provide a modest design and not contain irrelevant information.
Match between the System and the Real World	The system should speak the user's language rather than system-oriented terms.

Table 7-3: Heuristics and their description (taken from Nielsen, 1993)

In addition, the purpose of this heuristic evaluation was to report any strenghts and weaknesses and the applicability of the user-adaptation approach provided by the MDL concept as applied to the IPNS rather than assessing general usability problems. In this regard, expert evaluators were individually given a written introduction to the research objectives, the MDL concept, and the IPNS prototype, to read (Appendix A (I: page 185)). Once they completed the introductory handout, the evaluators were presented with the system and given the opportunity to become familiarised with the system and its tools. Then, the evaluators examined the prototype – 'walk through' the system, and judged its conformity with employed heuristics based on the 5-point Likert Scale – a measurement which respondents are requested to specify their level of agreement or attitude, from unfavourable to favourable, towards each of the statements being considered in the questionnaire. Expert evaluators were also asked to rationalise issues regarding good and bad aspects of the applicability of the prototype and to give additional comments for potential improvements in the future. In addition, at the end of the session, the evaluators discussed and formed an informal focus group to reflect on what they had found out, where they agreed and disagreed, and how they thought they would react if dissimilar ways of applying the concept to the system were proposed. The result of the heuristic evaluation will be presented in Chapter 8.

Secondly, the **empirical evaluation** or **users evaluation** was aimed at attaining *the usefulness of the user-controlled adaptation provided by the MDL concept*, that is, to find out whether or not the user adaptation provided by the MDL concept as applied to the IPNS prototype was useful and meaningful to users. The usability criteria used for this empirical evaluation are based on ISO/DIS 9241-1 (*effectiveness, efficiency,* and *user's satisfaction*) as follows:

- *Effectiveness* (e.g. solve prolific linking or irrelevant links, ease of navigation, make sense to users, appropriate users interface);
- *Efficiency* (e.g. maximise user control and freedom, speed of navigation, and percentage of task completed, efficiency of use);
- *User's Satisfaction* (e.g. user's opinion about the system, whether the user likes interacting with the prototype, and the user prefers the MDL concept as applied to the IPNS).

Within this evaluation, each user was introduced to the prototype and had hands-on with the system in order for them to become familiar with it. The user was requested to read a written introduction to the MDL concept and the IPNS prototype before conducting their evaluation (Appendix B (I: page 190)). This was to provide uniformity in the evaluation process (Wills, 2000). *Questionnaires* were used as a means for information gathering about the prototype. This information provided both objective and subjective data about the system. The objective data was obtained from a set of tasks in the established experiment users performed based on dependent factors, that is, *percentage of task completed* and *percentage of navigation completed (speed of navigation)*, respectively; whereas the subjective data was acquired based on the *user's opinion* in the questionnaire. The scales used for measuring user's opinion or satisfaction was based on the Software Usability Measurement Inventory (SUMI)– *Affect, Control, Efficiency, Helpfulness,* and *Learnability* (Kirakowski and Corbett, 1993), and scales for evaluating industrial hypermedia – *Navigation* and *Comprehension* (Wills, 2000), as exhibited in Table 7-4. Appendix B (V: page 209) lists all questions used in each scale.

Measurement	Definitions
Affect	User's emotions toward the use of the system.
Control	The degree to which the user feels that they are in control.
Efficiency	The degree to which users can complete tasks in a direct and timely fashion.
Helpfulness	The extent to which the system assists the user in a situation.
Learnability	The degree to which the system is easy for users to learn how to use.
Navigation	The ability for users to move around the system.
Comprehension	The degree to which users can understand the interaction with the system.

Table 7-4: Scales for measuring user's satisfaction (modified from Wills, 2000)

To validate the data from the experiment and test hypotheses designated for each task, the use of statistical analysis was adopted. SPSS was particularly chosen to present the outcome (Field, 2005). The next section gives a summary of tasks in the experiments and their rationales.

7.6 Experimental Design

The subjects for the empirical evaluation (users evaluation) were randomly assigned into Group 2.1 and Group 2.2. Each group was initially presented with one of three different systems, depending on the hypothesis being tested in each experiment *non-personalised system* (system Non link); *system with all links augmentation but no control over links presentation* (system All links); and *system with control over links personalisation and presentation* (IPNS). A summary of the experiments and their purposes is given as the following:

- *Experiment 1*: To investigate the effectiveness of the user-controlled adaptation provided by the MDL concept as applied in IPNS in comparison to navigation without the presence of personalised tools.
- *Experiment 2 (a)*: To examine the efficiency of the user adaptation provided by the MDL concept as applied in the IPNS in comparison with the system without the presence of personalised tools.
- *Experiment 2 (b)*: To examine if users prefer the user-controlled adaptation provided by the MDL concept as applied in IPNS more than non-personalised systems.
- *Experiment 3*: To study the user's satisfaction towards the usefulness of the user-controlled adaptation provided by the MDL concept as applied to the IPNS.

7.6.1 Experiment 1

In **Experiment 1**, the main concept was to compare the two systems: one was the non-personalised system (system Non link) and another was the IPNS prototype. The task for the Experiment 1 was to *find answers for the established questions* – one using the system Non link and another using the IPNS. The questions for the two groups were the same (the difference was only in which system they used to find the answers), and all of which were chosen concepts and terms that were part of, and could be found in, the subject domain. There were nine questions altogether for the subjects to complete in approximately 15 minutes. The subjects were asked to complete all questions or as many questions as possible and write down the time taken and completed. Group 2.1 was given to start with the system Non link (control system) and carry out the task (Task 1 for Group 2.1); whereas Group 2.2 was given to begin with the IPNS system and accomplish the task (Task 1 for Group 2.2). Then, the two groups changed the condition, which is, Group 2.1 carried out the task using the IPNS (Task 2(a) for Group 2.1) and Group 2.2 continued with the task using the system Non link (Task 2(a) for Group 2.2. The dependent variable required was the *percentage of task completed*. Tasks for the Experiment 1 for the Group 2.1 can be found in Appendix B (III-a: page

194) and (III-b: Q3: page 196), and for the Group 2.2 subjects can be found in Appendix B (IV-a: page 201) and (IV-b: Q3: page 204).

7.6.2 Experiment 2(a)

With respect to **Experiment 2(a)**, the aim was to compare the system with links augmentation where users have no control over links presentation and personalisation (System All links), with the IPNS prototype. The task for this experiment was to *locate some of the terms residing in the system (subject domain)*, where the subjects were asked to write down the start time and finish time. The *percentage of navigation completed (speed of navigation)* of each user was monitored and calculated. Group 2.1 was assigned to complete the task with the System All, whereas Group 2.2 was to carry out the task with the IPNS prototype. Appendix B (III-b: Q5: page 197) and (IV-b: Q5: page 205) present the task for the Experiment 2(a) for Group 2.1 and Group 2.2, correspondingly.

7.6.3 Experiment 2(b)

Concerning **Experiment 2(b)**, both groups of subjects were assigned to answer the questionnaries. The rationale for this experiment was to obtain the users' subjective feedback about the systems. Users were requested to answer the questionnaire related to each individual system qualitatively and to compare the three systems and list the system of preference. The questionnaires for Experiment 2(b) can be found in Appendix B (III-b: Q18: page 198) for the Group 2.1 subjects and (IV-b: Q19: page 206) for the Group 2.2 subjects.

7.6.4 Experiment 3

In **Experiment 3**, both groups of subjects were also assigned to answer the questionnaries. The aim was to obtain the users' subjective feedback merely about the IPNS prototype in which the subjects were assigned to complete the questionnaire with the 5-point Likert Scale. The established criteria were taken from Software Usability Measurement Inventory (SUMI) (Kirakowski and Corbett, 1993) and scales for evaluating industrial hypermedia (Wills, 2000). The questionnaires for Experiment 3 can be found in Appendix B (V: page 209) for both groups.

7.7 Summary

This chapter has presented the background to evaluation. It has covered the evaluation of human computer interfaces, evaluation of hypermedia systems and evaluation of adaptive hypermedia systems. This chapter has also described the evaluation approach used to evaluate IPNS. There are two methods used in evaluating IPNS; heuristic evaluation to measure the applicability of the user-controlled adaptation provided by the MDL concept as applied to the IPNS prototype, and empirical evaluation to assess the usefulness of the user-adaptation approach provided by the MDL concept. The next chapter presents the results of the evaluation process undertaken.

Chapter 8 Evaluation Results

8.1 Introduction

This chapter presents the results of the heuristic evaluation and empirical evaluation. It will also discuss these results in the context of IPNS and provide some answers to the hypotheses proposed by this work.

8.2 Heuristic Evaluation

Although heuristic evaluation is a common usability evaluation technique, used to find problems with an interface, this research employed heuristic evaluation to assess whether the user-controlled adaptation provided by the MDL concept as applied to the IPNS was applicable. A set of nine independent expert evaluators individually performed tasks on IPNS and then critically judged the prototype based on established heuristics, indicating their response to each heuristic on the form given (see appendix A (II: page 188)). Responses were coded as 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) and 5 (strongly agree) on a Likert scale. Figure 8-1 presents the overall results of the heuristic evaluation.

As can be seen in Figure 8-1, the overall result shows that there was no major difference amongst the nine experts. For most heuristics, the responses elicited ranged between *strongly agree* and *neutral*. None of the experts *strongly disagreed* with any of the nine heuristics. This indicated that the user-adaptation approach provided by the MDL concept did conform to its requirements and heuristics. For instance, all expert evaluators *agreed* to *strongly agreed* with the heuristic '*Flexibility and Efficiency of Use*', that is, the prototype system was able to deliver its functionality (i.e. the presented links were rightly functional and acceptable) both to experienced and inexperienced users, and allowed users to perform their task). Most expert evaluators agreed that the MDL concept as applied in the prototype did enable the user to choose the system functions (i.e. link presentation and personalisation) and allowed the users to have control and freedom in interacting with the system (the heuristic '*User control and freedom*').

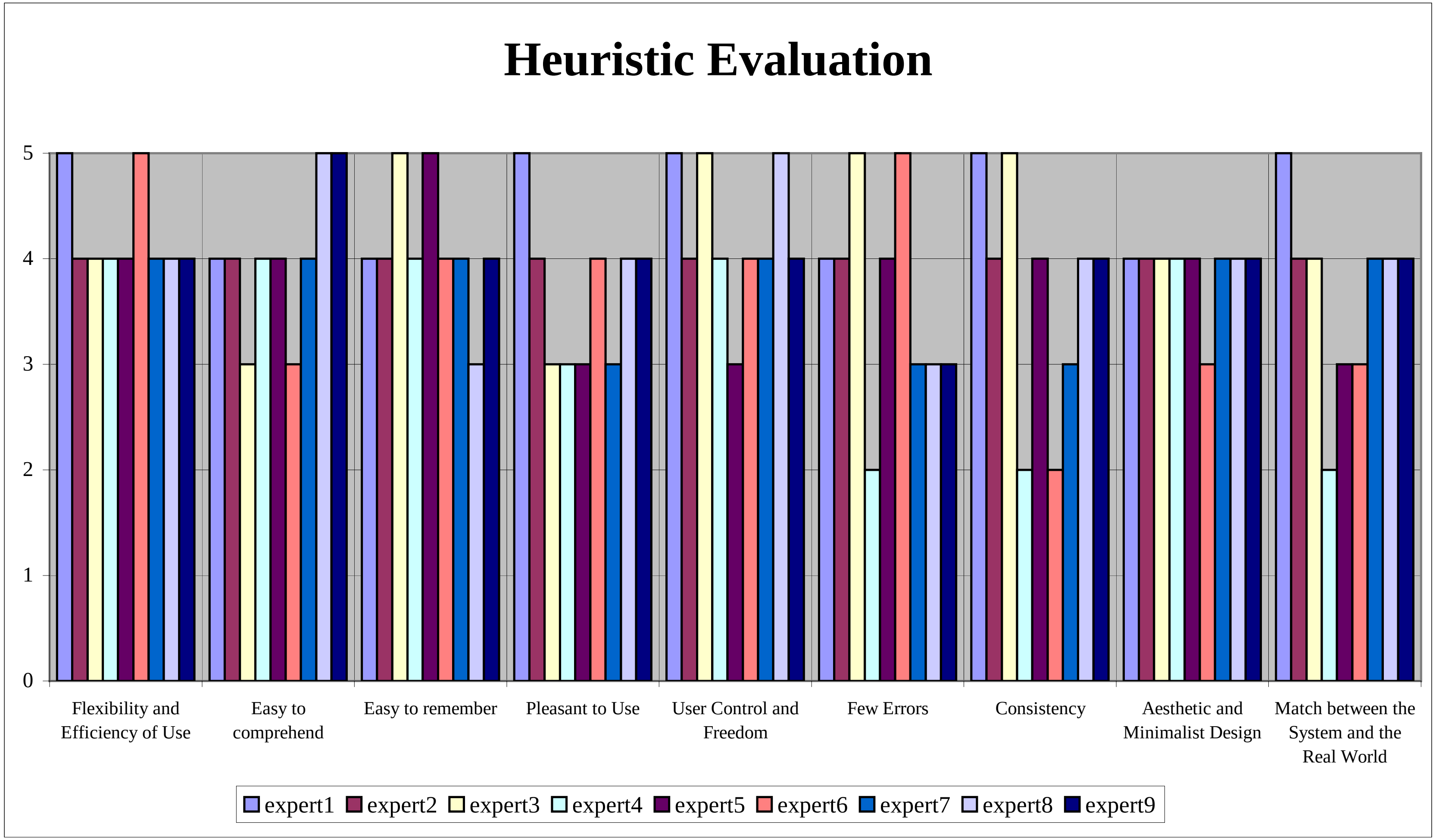


Figure 8-1: The overall result of the heuristic evaluation

Similarly, the results from the experts indicated that the IPNS prototype provided a modest design and did not contain irrelevant information (the heuristic '*Aesthetic and minimalist design*').

However, there were also some levels of disagreement between one of the experts and the remaining eight that the prototype system comformed with the following heuristics: the heuristics '*Few errors*' (i.e. the system generated no error or few errors); '*Consistency*' (i.e. the use of language and format of the system); and '*Match between the System and the Real world*' (the system spoke the user's language rather than use system-oriented terms).

With respect to individual heuristics, Figure 8-2 summarises the percentage of each heuristic. The complete list of all expert responses can be found in Appendix C (I: page 211).

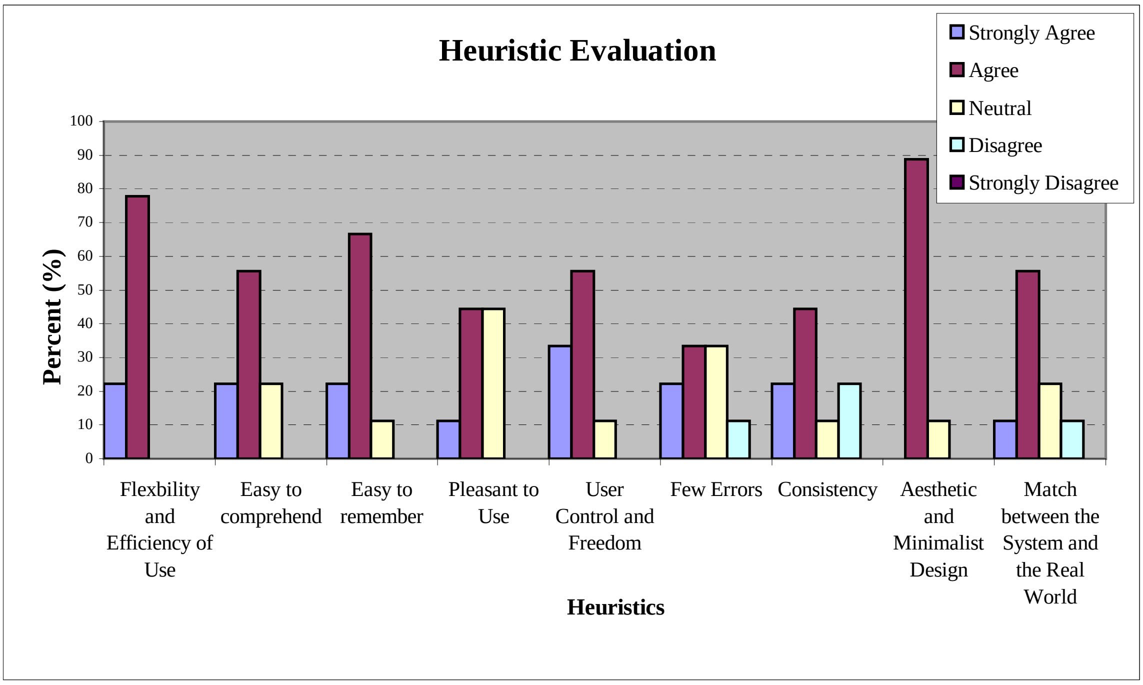


Figure 8-2: The percentage of each heuristic

8.2.1 Additional Comments from the Heuristic Evaluation

In addition to the critical examination using heuristics, the evaluators made additional comments. An informal focus group was also formed, using three of the experts, to provide insightful feedback. The complete list of all expert comments and issues raised in the informal focus group discussion can also be found in Appendix C

(I: page 211). Below is a summary of the key points made by the experts, relating to each heuristic.

Flexibility and Efficiency of Use (the system should be able to deliver its functionality – i.e. the presented links are rightly functional and acceptable – either to experienced, or inexperienced users, and allow users to perform their task)

- The prototype was common for Web users. The users could therefore use the system to perform their task without great difficulty.
- The system provided more functionality and the tools were user-friendly. They reacted immediately with input. However, more clarification about how to use the system would be essential and useful for users.

Easy to Comprehend (the user should find it easy to understand the interaction with the system i.e. interacting with the links interfaces is easy to understand)

- *Personalised Links Assistant* was a very good idea and easy to use. *Inquiry Assistant* interface was a good notion but the presentation of results was less clear than it could have been. Definition of relationship types for the domain ontology was unclear to every user. Occasionally, the given links from the *Inquiry Links* tool were not easy to understand.
- Appearance and disappearance of links definitely satisfy users.

Easy to Remember (the user should not have to remember instructions in order to interact with the system)

- It was easy to remember, apart from the definition of relationship types for the *Inquiry Assistant* interface.
- The proposed concept was simply implemented. The design of the system was not too complex. The assistant tools were designed and placed on top of the top navigation menu. Users could remember these tools and where to find them. The “Select Text” button at the bottom of each page could warn users that there was a help function to assist users in finding more explanation when they wanted one. However, users needed to learn how to use the system before using it.

Pleasant to Use (the system should provide user-friendly interface and the user should be enjoyable interacting with the system)

- There should be a "Back" button to point back to the search's result tree from the *Inquiry Links* tool (or any previous page about what a mistake was made).
- The design of the "Select Text" button in each page could be made more flexible with the design of the left mouse click.

User Control and Freedom (the user should be able to choose the system functions (i.e. links presentation and personalisation) and have control and freedom in interacting with the system)

- It was good that the system allowed users to select which dimensions of links to appear and it saved time for users to be able to get rid of irrelevant contents (links).
- The system was preferable to users because it provided functions such as *Personalised Links Assistant* to present users with something users could decide to see at a time. **"No link"** option could make the experienced users or expert users with a non-link insertion version. **"All links"** selection could make inexperienced users see all presenting links.
- With the *Personalised Links Assistant* tool, one expert expressed that he felt in control (except when the system crashed).

Few Errors (the system should be error free or generate few errors i.e. the system should deliver links rightly according to its function and interface)

- Links all seemed to be relevant. However, sometimes the system crashed while browsing the documents, which resulted in the invisibility of links when there were supposed to be some links displayed.
- There were few errors from the system.

Consistency (the use of language and format of the system should be consistent)

- The system was consistent. All pages used same format, position, etc. However, some technical terms should be replaced, as they were unknown to some inexperienced users.

- *Follow Links* failed to find a link on a keyword such as “dough” but one existed.

Aesthetic and Minimalist Design (the system should provide a modest design and not contain irrelevant information)

- The design of the system was good and it was easy to handle and follow. The reaction time was short. The *Personalised Links Assistant* was good. The results from *Inquiry Assistant* in the textual form were a bit difficult to use and see. It would be easier to see and read if the results were displayed in the visual graph. In addition, the button for the *Follow Links* function should be placed with the other assistant tools at the top of the navigation menu.
- Linking in body was good but still I found many keyword links repeating themselves e.g. “dough”.
- It would be beneficial to look at some text processing techniques to parse the content before adding links because there was still some irrelevant links e.g. “rope” in a word “property”.

Match between the System and the Real World (the system should speak user’s language rather than system-oriented terms)

- It might be difficult for some users to understand how the *Inquiry Links* and the *Follow Links* tool would help in their navigation. Maybe more background information was needed.
- The *Inquiry assistant* interface failed, otherwise it appeared fine.
- It would be better to replace some technical wording in relationship types with simpler meanings.

Other comments

- The design of the assistant tools could be improved to make it more usable. For instance, it would be useful to know which linkbase the links were appearing from, or which dimension the word came from e.g. different colour per linkbase.
- An issue such as giving too much assistance could take time for users to configure the setting that they want, needs to be taken into consideration. This is

because it could cause users to discontinue using the system and the tools provided.

8.3 Empirical Evaluation

As previously described in Section 7.5.2, the objective of this user-based evaluation was to measure the usefulness of the user controlled adaptation provided by the MDL concept as applied in the IPNS prototype. Based on ISO/DIS 9241, usability criteria (*effectiveness*, *efficiency*, and *user's satisfaction*) was used as the evaluation criteria. The studies were divided into three experiments. Each has its own purposes and hypotheses postulated, and the task in each experiment was designed to evaluate its rationales.

In an experimental study, a prediction about the effects of one or more of the objects of the study is formulated as an *experimental hypothesis* and needs to be tested, the results of which would indicate whether or not the prediction is supported (Greene and D'Oliveira, 1999). An experimental hypothesis (H_1) is essentially tested against a *null hypothesis* (H_0). On the one hand, the experimental hypothesis states that there is significant difference in what is being proposed or measured. On the other hand, the null hypothesis presumes that there is no significant difference and the experimental results are brought up by chance, or are randomly caused by the variation in people's performance or measurement ('independent variable') rather than the predicted effects of what is being proposed ('dependent variable') (Greene and D'Oliveira, 1999). Statistical methods are required to validate the data collection in the experiment and to state whether the null hypothesis is accepted or rejected for the prediction.

8.3.1 **Experiment** ***1: To investigate the effectiveness of the user-controlled adaptation provided by the MDL concept as applied in the IPNS prototype in comparison to navigation without the presence of personalised tools***

Task: The users in Group 2.1 and Group 2.2 were asked to generally explore the designated system and use the system to answer nine questions in approximately fifteen minutes. The users were requested to write down the time when they started and finished. Then, both groups were required to repeat the task but this time working with the different system. Table 8-1 shows the task allocation for both groups of subjects.

Appendix B (III-a: page 194) and (III-b: Q3: page 196) document the tasks for Group 2.1, and Appendix B (IV-a: page 201) and (IV-b: Q3: page 204) present the tasks for Group 2.2.

Group	Experimental conditions	
	Condition 1	**Condition 2**
Group 2.1	System Non link (Non-personalised system)	IPNS
Group 2.2	IPNS	System Non link (Non-personalised system)

Table 8-1: The allocation of subjects for Experiment 1

Independent variable: System Non link and IPNS.

Dependent variable: Percentage of task completed.

Hypothesis 1:

H_1: The *percentage of task completed* is significantly improved by the set of links presented by the IPNS prototype in comparison to navigation without the presence of personalised features.

H_0: The *percentage of task completed* is *not* significantly improved by the set of links presented by the IPNS prototype in comparison to navigation without the presence of personalised features.

Result for Experiment 1:

The **percentage of task completed** was defined as the overall percentage of task completion that took account of the time a user used to finish the task *(time)*, the number of questions that the user completed *(completion)*, and the number of questions that the user got them right *(score)*. The percentage of task completed was obtained from the sum of the following measurements:

- *Time percentage* (maximum 100%);
- *Completion percentage* (maximum 100%);
- *Score percentage* (maximum 100%);

giving the potential for a maximum of 300%.

Time percentage was calculated based on the time allowance for a user to complete the task (i.e.15 minutes), meaning that if a user finished answering the questions within less than 15 minutes, the user would then obtain 100 percent. The longer than 15 minutes the user spent on completing the task, the lower percentage the user would attain. Table 8-2 describes the calculation of the time percentage.

Time (min)	Percentage
< 15	100
16-19	90
20-34	80
> 35	70

Table 8-2: The calculation of Time percentage

Completion percentage was defined as the percentage of the number of questions that a user completed out of nine questions, that is, if a user completed all nine questions, the user would gain 100 percent. The less questions the user completed, the lower proportion of percentage reduced from 100 percent the user would achieve. Table 8-3 demonstrates the calculation of the completion percentage.

No. of Questions	Completion Percentage
9	100
8	88.89
7	77.78
6	66.67
5	55.55
4	44.44
3	33.33
2	22.22
1	11.11

Table 8-3: The calculation of Completion percentage

Similarly, *Score percentage* was calculated in the same manner as the completion percentage. However, the number of questions in this case was the number of questions that the user answered correctly. If a user answered all nine questions accurately, the user would obtain 100 percent. The more questions the users answered correctly, the higher percentage the user would obtain. Table 3 shows the calculation of the Score percentage.

No. of Questions	Score Percentage
9	100
8	88.89
7	77.78
6	66.67
5	55.55
4	44.44
3	33.33
2	22.22
1	11.11

Table 8-4: The calculation of Score percentage

The calculation of the percentage of task completed for each subject can be found in Appendix C (II: page 216).

Based on the 'one-tailed related *t* test (paired-samples *t* test)'– a model used to compare two different means of a repeated measure design (i.e. same subjects are doing both conditions)(Greene and D'Oliveira, 1999; Field, 2005) – Table 8-5 illustrates the descriptive statistics for the two systems, and Table 8-6 shows that the null hypothesis for Hypothesis 1 was rejected ($t(15) = -3.329$, $p= 0.005/2$ (1-tailed), i.e. $p<0.05$). This revealed that the set of links presented by the IPNS prototype has significantly improved the *percentage of task completed* in comparison to navigation without the presence of personalised features. Figure 8-3 exhibits the mean difference of the percentage of task completed in the graphical form. Appendix C (II: page 216) documents the trial data for the experiment 1.

Percentage of task completed	Mean	No. of subjects	Std. Deviation	Std. Error Mean
System Non link (Non-personalised System)	222.64	16	30.94	7.736
IPNS	244.79	16	30.97	7.743

Table 8-5: Descriptive statistics for the two systems in Experiment 1 produced by SPSS

Percentage of task completed difference	Paired Differences (95% Confidence Interval)			*T*	df	Sig (2-tailed)
	Mean	Std. Deviation	Std. Error Mean			
Non-personalised system – IPNS	-22.15	26.62	6.65482	-3.329	15	0.005

Table 8-6: Result produced by SPSS for the 'related *t* test' for Experiment 1

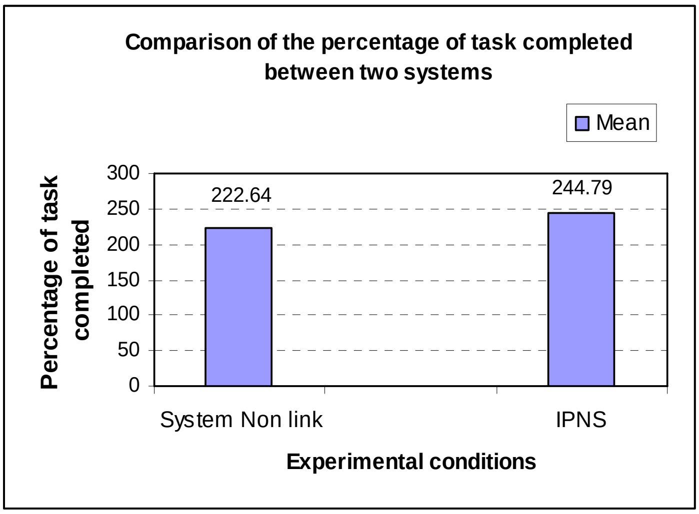


Figure 8-3: Percentage of task completed between non-personalised system and IPNS

Comments:

The original number of subjects (N) was actually twenty four. However, the trial on the first day which included eight respondents (four for each group) had to be taken out from the data analysis which therefore resulted in sixteen subjects instead of twenty four for the analysis of data. This was due to the fact that the task asked the subjects to find information for the nine questions but did not guide the users where to find the information (e.g. look in Carbohydrate >> Starches). As a result, the users who did not have the knowledge background about the subject domain had to go through every single page and this might not provide the answer for what we were looking for (percentage of task completed in approximate time limit). At the end of the session, the respondents gave some feedback regarding this issue. In order to reflect on these comments, the second trial eliminated this problem by suggesting the location where the subjects would find the answers for the questions but the subjects still had to look through and locate the materials for the questions themselves.

8.3.2 Experiment 2(a): To examine the efficiency of the user adaptation provided by the MDL concept as applied in the IPNS in comparison with the system without the presence of personalised tools

Task: The users were asked to locate the required terms using two different systems and write down the start and finish time. Group 2.1 used the System All links (System with all links augmentation but no control over links presentation), whereas Group 2.2 used the IPNS prototype to perform the task, as shown in Table 8-7. Appendix B (III-b:

Q5: page 197) and (IV-b: Q5: page 205) documents this task (for Group 2.1 and Group 2.2, respectively).

Group	Experimental Condition
Group 2.1	System All links (Non-personalised system)
Group 2.2	IPNS

Table 8-7: The allocation of subjects in the Experiment 2 (a)

Independent variable: System All links and IPNS.

Dependent variable: Percentage of navigation completed.

Hypothesis 2:

H_1: The set of links presented signficantly increases the percentage of navigation (speed of navigation) completed in comparison to navigation without the presence of personalised features.

H_0: The set of links presented does *not* increase the percentage of navigation completed (speed of navigation) in comparison to navigation without the presence of personalised features .

Result for Experiment 2(a):

In this experiment, the **percentage of navigation completed** was used to define the speed of navigation (i.e. the higher percentage of navigation completed, the higher speed of navigation). It was obtained in the similar manner to the percentage of task completed in Experiment 1; however, in this case, it was merely the sum of the following two measurements, giving a maximum of 200%:

- *Time percentage* (maximum 100%), calculated from the time the user took to complete locating the required terms (i.e. the longer a user spent on locating the required terms than 4 minutes, the lower percentage the user would gain); and
- *Percentage of tasks found* (maximum 100%), obtained from the number of required terms that a user could locate (i.e. if a user could locate all required terms, the user would obtain 100 percent, and the more the required terms the user found, the closer to 100 percent the user would achieve).

The difference between the *percentage of task completed* and *percentage of navigation completed* resulted from the nature of their task in the experiment. On the one hand, the *task in Experiment 1* required the user to answer the established questions; therefore, there were three factors involved in measuring the task completion: time, number of questions completed, and score of questions that the user answered correctly. On the other hand, the t*ask in Experiment 2a* required the user to locate the required terms, which in this case, if the user could locate out a required term, it could then be assumed that the user scored one point. As a consequence, the score factor would represent the same measurement as the number of required terms found, and hence could be removed from the calculation. Table 8-8 represents the calculation of the Time percentage, and Table 8-9 shows the calculation of the Percentage of tasks found.

Time (min)	Time Percentage
1	100
2	90
3	80
4	70
5	60
6	50
>7	40

Table 8-8: The calculation of the Time percentage

Time (min)	Percentage of tasks found
4	100
3	90
2	80
1	70

Table 8-9: The calculation of the Percentage of tasks found

The trial data and the calculation of the percentage of the navigation completed for each subject can be found in Appendix C (III: page 217).

Based on the 'one-tailed independent *t* test' – a technique used to compare two means where these means have come from two different group of subjects and each group performs different condition (an unrelated measure design)(Greene and D'Oliveira, 1999; Field, 2005), Table 8-10 presents the descriptive statistics for the two systems and Table 8-11 demonstrates the output from the independent *t* test. As can be seen in the figures, on average, the percentage of navigation completed performed by IPNS (M = 182.50, SE=5.26) was greater than by the control system (M = 175.00, SE = 8.018). This difference was however not significant *t*(14) = -0.782, p = 0.225 (one-tailed) i.e. p > 0.05 and resulted in the null hypothesis for Hypothesis 2 being accepted. That is the set of links presented has not increased the percentage of navigation completed in comparison to the system with no presence of personalised features.

Percentage of navigation completed	N	Mean	Std. Deviation	Std. Error Mean
System All links (Non-personalised)	8	175.00	22.68	8.018
IPNS	8	182.50	14.88	5.26

Table 8-10: Descriptive statistics for the systems in Experiment 2(a) produced by SPSS

t-test (Equal variances assumed)				
T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
-0.782	14	0.447	-7.50	9.59

Table 8-11: Result produced by SPSS for the 'independent *t* test' for Experiment 2(a)

Comments:

In addition to the task in Experiment 1, the first trial of this experiment has been taken out from the data analysis for the same reason (i.e. there was no suggestion given where to locate the require terms). Therefore, this resulted in the number of each group reduced to eight participants instead of twelve. This concern will also have an effect on Experiment 2(b).

8.3.3 Experiment 2(b): To examine if users prefer the user-controlled adaptation provided by the MDL concept as applied in the IPNS more than non-personalised systems

Task: The participants were requested to provide subjective feedback about the three systems they had been using, make a rational comparison between them, and answer eleven questions by which to emphasise their opinions. Each group was assigned the same task as shown in Table 8-12. The questionnaires for Experiment 2(b) can be found in Appendix B (III-b: Q18: page 198) and (IV-b: Q19: page 206) for the Group 2.1 and 2.2 subjects, respectively.

Group	Task
Group 2.1 and Group 2.2	Make a subjective comparison between the three systems (system Non link, system All links, IPNS) that have been used. Answer the questionnaire.

Table 8-12: The allocation of the subjects in the Experiment 2(b)

Result for Experiment 2(b):

Appendix C (IV: page 218) presents all the data from the trial for the experiment 2(b).

Hypothesis 3:

H_1: Users *prefer* the user-controlled adaptation provided by the MDL concept as applied in IPNS than non-personalised systems.

H_0: Users have *no* preference between the user-controlled adaptation provided by the MDL concept as applied in IPNS and non-personalised systems.

To test this hypothesis, the question (*'I would prefer to use the following systems (system Non link, system All links, and IPNS) to locate the documents and perform all required tasks in the future'*) in the questionnaire was analysed.

The '*one-sample Chi-square*' was employed for the purpose of data analysis. *Chi-square* is a statistical model used to make predictions about categorical variables, or counting how many different subjects will fall into one or more categories, where each subject can be assigned to only one category (Greene and D'Oliveira, 1999), and the *'one-sample Chi-Square'* is used to compare observed frequencies with what would be expected if the frequency was equal for all events (Foster, 2001). As shown in Table 8-13, the null hypothesis for Hypothesis 3 was rejected ($p = 0.039$, i.e. $p < 0.05$), indicating that the obtained frequencies differed from those expected under the null hypothesis by more than could happen by chance (Howell, 2002). That is there was significant user preference in using the system (amongst the three systems).

Subjective feedback on the user preference for a system

	Observed N	Expected N	Residual
System Non link	4	5.3	-1.3
System All links	2	5.3	-3.3
IPNS	10	5.3	4.7
Total	16		

Chi-Square(a)	6.500
Df	2
Asymp. Sig.	0.039

a. 0 cells (.0%) have expected frequencies less than 5.
The minimum expected cell frequency is 5.3.

Table 8-13: Result produced by SPSS for the three systems in Experiment 2(b)

To further investigate by comparing between the non-personalised systems (grouping together system Non link and system All links) and the IPNS, Table 8-14 summarises this finding.

System	Observed (O)	Expected (E)	O-E	$(O-E)^2$	$(O-E)^2/E$	$\chi 2$
Non-Personalised systems	6	10.66	-4.66	21.716	2.037	6.1298
IPNS	10	5.33	4.67	21.809	4.092	

Table 8-14: The statistical result for non-personalised systems and the IPNS

As can be seen, the value of Chi-square ($\chi 2$) (hand calculated) = 6.1298 on 1 *df*, whereas from the $\chi 2$ distribution table, $\chi 2_{(0.05)}$ (1 df) = 3.84 (i.e. cuts off the upper 5% of the distribution)(Howell, 2002). As $\chi 2_{obt} > \chi 2_{crit}$ (i.e. 6.1298 > 3.84), the null hypothesis for Hypothesis 3 was therefore rejected which indicated that users significantly preferred the MDL concept as applied in the IPNS than non-personalised systems.

Hypothesis 4:

H_1: The IPNS with the links presentation and personalisation tools is useful as it allows the selection of links to be displayed based on users' preference.

H_0: The IPNS with the links presentation and personalisation tools is *not* useful.

This hypothesis was tested by taking into consideration the question (‘*I found the IPNS prototype was useful as it allowed me to select the links to be displayed on my preference*’) in the questionnaire. The ‘one-sample Chi-Square’ model was chosen as a statistical model instead of the ‘one-sample *t* test’, as the author was purely interested in the data frequency counts and in comparing observed frequencies with expected ones (Foster, 2001; Diamond and Jefferies, 2001). However, the one-sample *t* test might have been more appropriate if the emphasis had been on the ordering of the agreement, how the score obtained varied from the neutral point (the test value), or the relationship amongst the agreements.

As shown in Table 8-15, the ‘one-sample Chi-Square’ technique resulted in the rejection of the null hypothesis for Hypothesis 4, i.e. Chi-Square = 5.281, p = 0.022 < 0.05. This indicates that the IPNS with links presentation and personalisation tools was significantly useful as it allowed the selection of links to be displayed based on users’ preference.

	Observed Value	Expected Value	Residual (O-E)	Chi-Square (a)	*df*	Asymp. Sig.
Agree	15	5.33	4.33	5.281	1	0.022
Not sure/ Disagree	1	10.66	-4.33			

(a) 0 cells (.0%) have expected frequencies less than 5.
The minimum expected cell frequency is 5.3.

Table 8-15: Result produced by SPSS for the subjective feedback on the ‘usefulness of the IPNS’

Hypothesis 5:

H_1: Users find that they have control over link presentation and personalisation in IPNS.

H_0: Users find that they do *not* have control over link presentation and personalisation in IPNS.

The question (‘*I found the IPNS enabled me to have control over the link presentation and personalisation, that is, I can select the links to be presented*’) in the questionnaire was analysed for this purpose. Again, the ‘one-sample Chi-Square’ test was chosen, and its result, as shown in Table 8-16, revealed that the null hypothesis for

Hypothesis 5 was rejected, i.e. Chi-Square = 12.500, p = 0.000, i.e. $p < 0.05$. Statistically, this confirms that users felt they were in control of link presentation and personalisation in the IPNS.

	Observed Value	Expected Value	Residual (O-E)	Chi-Square (a)	df	Asymp. Sig.
Agree	12	5.33	6.67	12.500	1	0.000
Not sure/ Disagree	4	10.66	-6.66			

(a) 0 cells (.0%) have expected frequencies less than 5.
The minimum expected cell frequency is 5.3.

Table 8-16: Result produced by SPSS for the subjective feedback on the 'user control' aspect of the IPNS

Other statistical results from the trial can be summarised in Table 8-17. The column 1 *df* represents the result gained from grouping 'not sure and disagree together' and compared it against the 'agree' opinion.

Subjective feedback	**Statistical results**
	1 *df* (**)
I found the ***IPNS*** prototype helped me find the document.	Chi-Square = 21.125 p=0.000
I found that there were too many links in ***System All links*** and some of these links were what I had already known.	Chi-Square = 9.031 p=0.003
I think ***the MDL concept*** and the ***Personalised Links assistant*** interface was useful as it allowed a same keyword to become different links based on the user's selection.	Chi-Square = 16.531 p=0.000
I think ***the MDL concept*** and the ***Personalised Links assistant*** interface could solve some of the problems of too many additional links inserting into the document, whereby these links might not be of concerns, not only in this specific domain, but also in bigger hyperspace.	Chi-Square = 16.531 p=0.000
I think the links presentation and personalisation interfaces were user-friendly and easy to use.	Chi-Square = 6.125 p=0.013
I would prefer to user the following system (*non-personalised system*, *IPNS*, *none*) for links presentation • ***IPNS***	Chi-Square =21.125 p=0.000

(**) It is correct to carry out a one-tailed chi-square only when there is just 1 *df* (Howitt and Cramer, 2005)

Table 8-17: Summary of the statistical results of the subjective feedback for Experiment 2(b)

8.3.4 **Experiment 3:** ***To study the user's satisfaction towards the usefulness of the user-controlled adaptation provided by the MDL concept as applied to the IPNS***

Task: After using all three systems, the subjects were asked to mentally compare the three systems and complete the questionnaire to provide another subjective feedback, but this time the emphasis was purely on the IPNS prototype and its conformity, where the respondents gave their viewpoints relating to the SUMI assessment scales (*Affect*, *Control*, *Efficiency*, *Helpfulness*, and *Learnability*) (Kirakowski and Corbett, 1993), and hypermedia scales (*Navigation* and *Comprehension*) (Wills, 2000) with the 5-point Likert scale grading from ‘Strongly Agree’, ‘Agree’, ‘Neutral’, ‘Disagree’ to ‘Strongly Disagree’. Each scale consisted of five statements. Both groups were given the same task, as shown in Table 8-18. At the end of the session, the users were requested to give their overall reactions to using the prototype system and the tools provided, as well as additional comments. The complete questionnaire can be found in Appendix B (V: page 209).

Group	Task
Group 2.1 and Group 2.2	Answer the users’ opinion questionnaire about IPNS

Table 8-18: The allocation of the subjects in the Experiment 3

Results for Experiment 3:

The results for this experiment are presented in the same manner as delivered in the questionnaire. Appendix C (V: page 219) documents a complete list of the trial’s results undertaken for the experiment and Appendix C (VI: page 221) presents the prepared data for the statistical analysis.

<u>Affect</u>

Statements 1-5 in this scale measured the users’ emotions toward the usage of the prototype system. Figure 8-4 presents a summary of the user’s opinions on the ‘Affect’ criteria. As can be seen in the figure, the results revealed that none of the users strongly disagreed with the statements in this scale. None disagreed that they did not enjoy interacting with the system, that they would not recommend the system to their colleagues, and that the prototype system was not enjoyable to use. 75% (eighteen users) agreed that the system was enjoyable to use. In addition, 67% (sixteen users) agreed that they would want to use the system on a regular basis.

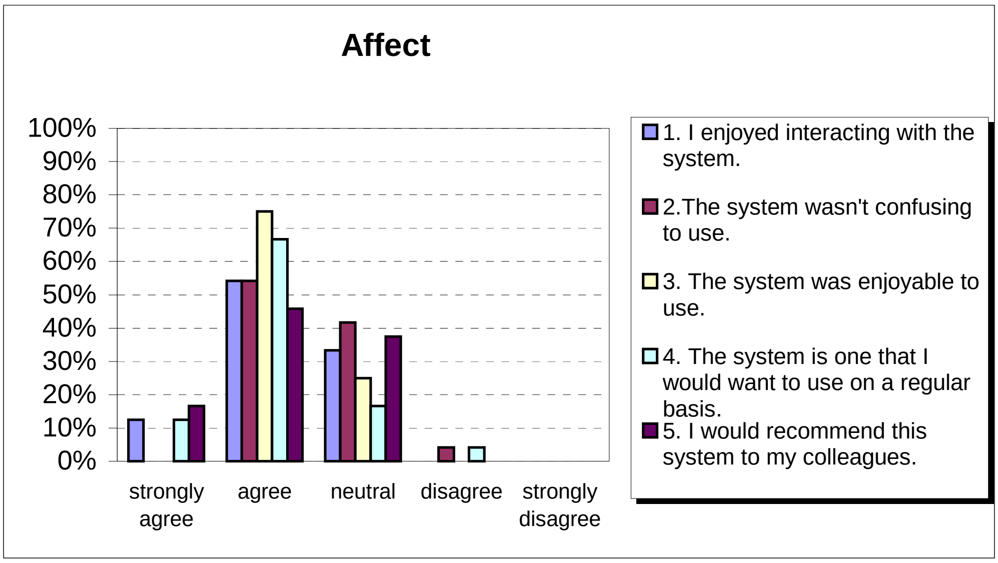


Figure 8-4: Subjective feedback on the 'Affect' aspect of the system

Hypothesis 6:

H_1: Users significantly like interacting with the system.

H_0: Users do *not* like interacting with the system.

Based on the 'one sample *t*-test' – a technique used to compare the mean of a sample with specified test value (Foster, 2001) – in this case we would like to see whether the mean of each scale is significantly different from 3 (the neutral point of the scale), as shown in Table 8-19, the null hypothesis for Hyphothesis 6 was rejected ($t(23) = 8.056$, $p<0.05$) indicating that the users significantly liked interacting with the system.

Scales	Statistical Results					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Affect	8.056	23	0.000	3.708	2.76	4.66

Table 8-19: Result produced by SPSS for the scale 'Affect'

Control

Statements 6-10 in the Control scale examined the degree to which the users felt that they were in control. As can be seen in Figure 8-5, a majority of the users felt that they were in control while using the system with 71% (seventeen users) agreed, 21% (five users) neither agreed nor disagreed, 4% (one user) strongly agreed and disagreed.

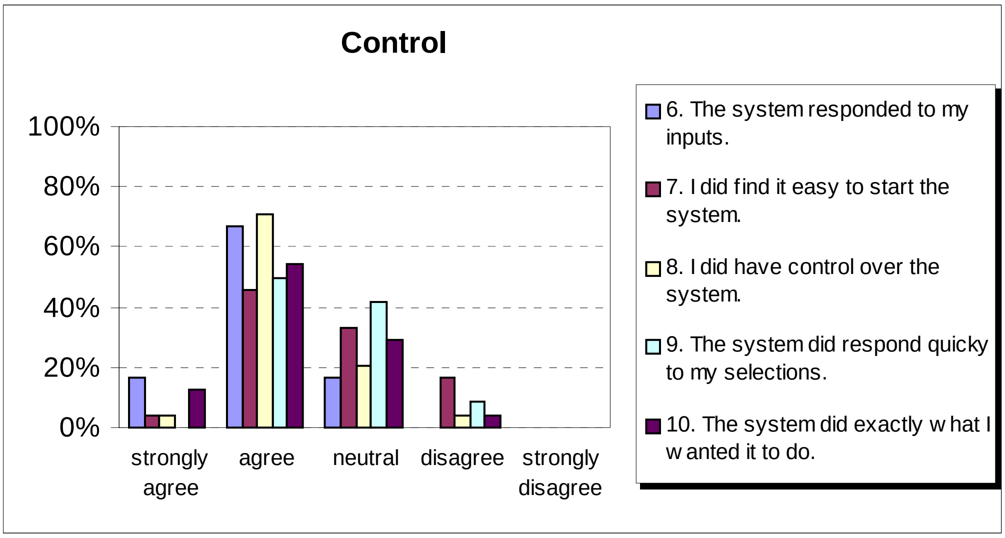


Figure 8-5: Subjective feedback on the 'Control' aspect of the system

Hypothesis 7:

H_1: The user adaptation provided by the MDL concept as applied in IPNS significantly allows users to have control over links presentation and personalisation.

H_0: The user adaptation provided by the MDL concept as applied in IPNS does *not* allow users to have control over links presentation and personalisation.

Derived from the 'one sample *t*-test' as shown in Table 8-20, the null hypothesis for Hypothesis 7 was rejected ($t(23) = 8.595$, $p < 0.05$) which indicated that the user adaptation provided by the MDL concept as applied in the IPNS significantly allowed users to have control over links presentation and personalisation.

Scales	Statistical Results					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Control	8.595	23	0.000	3.292	2.50	4.08

Table 8-20: Result produced by SPSS for the scale 'Control'

Efficiency

Statements 11-15 of the user's opinion questionnaire measured the degree to which users could complete tasks in a direct and timely fashion. Figure 8-6 presents a summary graph of the users' opinions concerning the efficiency's statements.

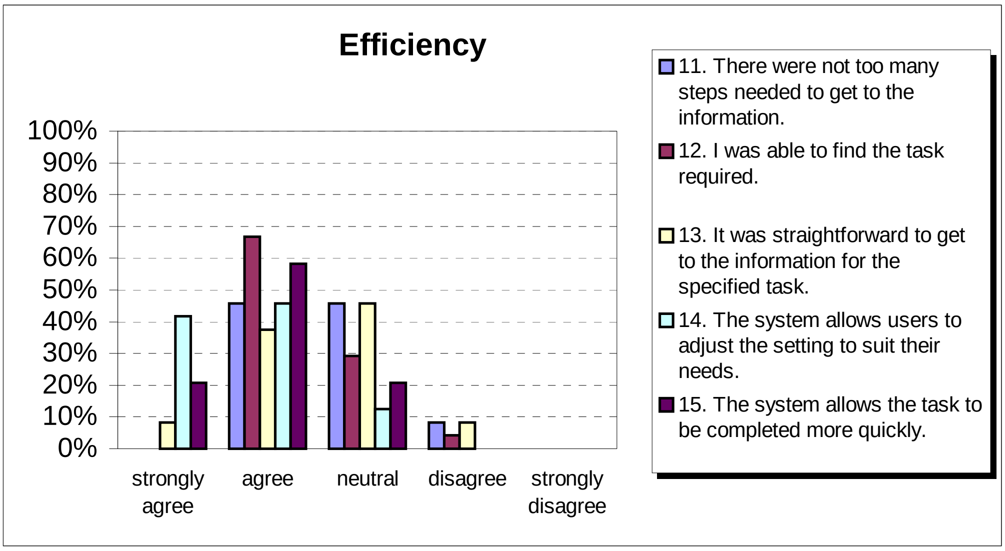


Figure 8-6: Subjective feedback on the 'Efficiency' aspect of the system

As can be seen in Figure 8-6, none of the respondents strongly disagreed that they could not complete tasks in a timely fashion while using the system. 58% (Fourteen users) agreed that the system allowed them to complete tasks more quickly, 21% (five users) strongly agreed, and 21% neither agreed nor disagreed. A similar result was obtained that 67% (sixteen users) agreed that they were able to find the task required using the system, 29% (seven users) neither agreed nor disagreed), and 4% (one user) disagreed.

Helpfulness

Five statements were assigned to assess the extent to which the system assisted the user in a situation. Figure 8-7 shows a summary of the responses about the helpfulness. As can be seen in the figure, a majority of the users agreed and strongly agreed that the system was helpful in finding what they needed, 67% and 17% respectively, whereas 12% neither agreed nor disagreed, and a small percentage disagreeing (one user). For the statement about the inquiry tools providing enough assistance, a majority of the users neither agreed nor disagreed (58.3%), 33.3% agreed, 4.2% strongly agreed, and 4.2% disagreed. 75% (eighteen users) agreed that they understood how to use the tool, 12.5% neither agreed nor disagreed, 8% (two users) strongly agreed, and 4.2% (one user) strongly disagreed. For the statement about 'the tools' being easy to use/interact with, 62.5% (fifteen respondents) of the twenty four respondents agreed, 12.5% strongly agreed, 12.5% neither agreed nor disagreed, 8.3% (two users) disagreed, and 4.2% (one user) strongly disagreed.

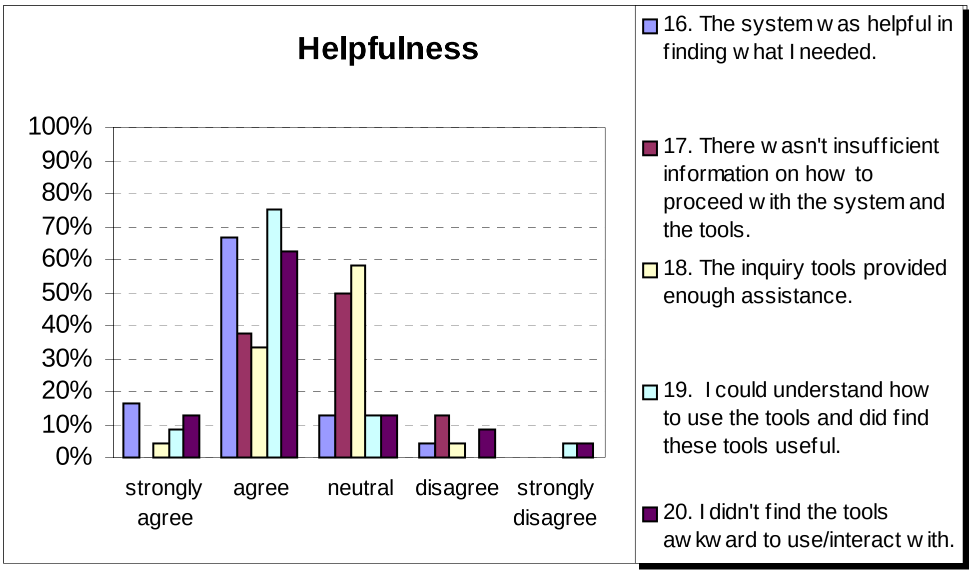


Figure 8-7: Subjective feedback on the 'Helpfulness' aspect of the system

Hypothesis 8:

H_1: The user-controlled adaptation provided by the MDL concept as applied in IPNS is significantly useful and helpful.

H_0: The user-controlled adaptation provided by the MDL concept as applied in IPNS is *not* significantly useful and helpful.

Based on the 'one sample *t*-test', as shown in Table 8-21, the null hypothesis for Hyphothesis 8 was rejected ($t(23) = 6.685$, $p < 0.05$) indicating that the MDL concept as applied in the IPNS was statistically significantly useful and helpful.

Scales	Statistical Results					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Helpfulness	6.685	23	0.000	3.125	2.16	4.09

Table 8-21: Result produced by SPSS for the scale 'Helpfulness'

Learnability

Statements 21-25 examined the degree to which the system was easy for users to learn how to use. Figure 8-8 gives a summary of the users' opinions about the learnability aspect of the system. As can be seen in the figure, none of the participants strongly disagreed that the system was not easy for users to learn how to use. A majority of users agreed and strongly agreed that they found the system easy to learn (75% (eighteen users) and 4% (one user), respectively), 17% (four users) neither agreed nor disagreed, and a very small percentage of disagreeing (4%, one user).

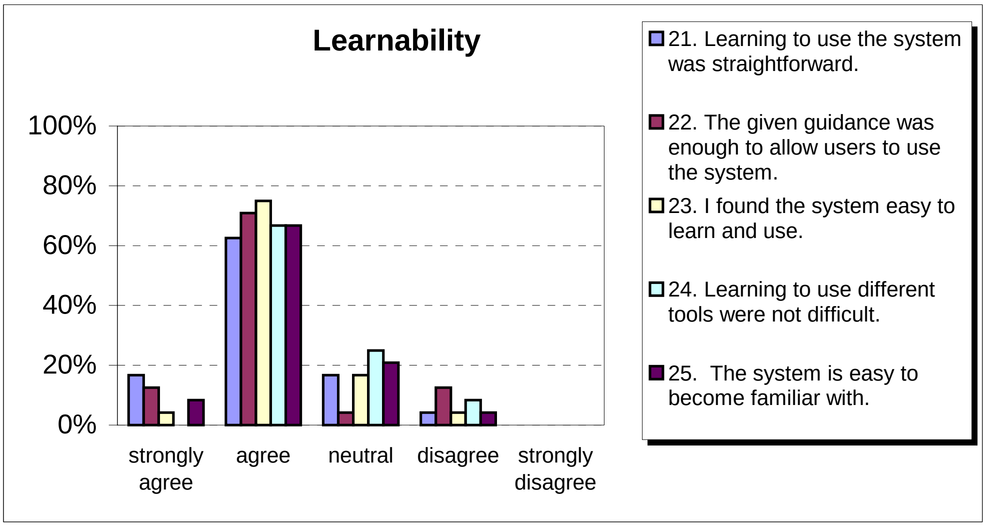


Figure 8-8: Subjective feedback on the 'Learnability' aspect of the system

Navigation

Statements 26-30 were set to determine the ability for users to move around the system. As can be seen in Figure 8-9, all respondents agreed that the system tools provided assisted them in navigation, with none disagreeing. Similarly, a major percentage of users found that the system tools useful with no one disagreeing.

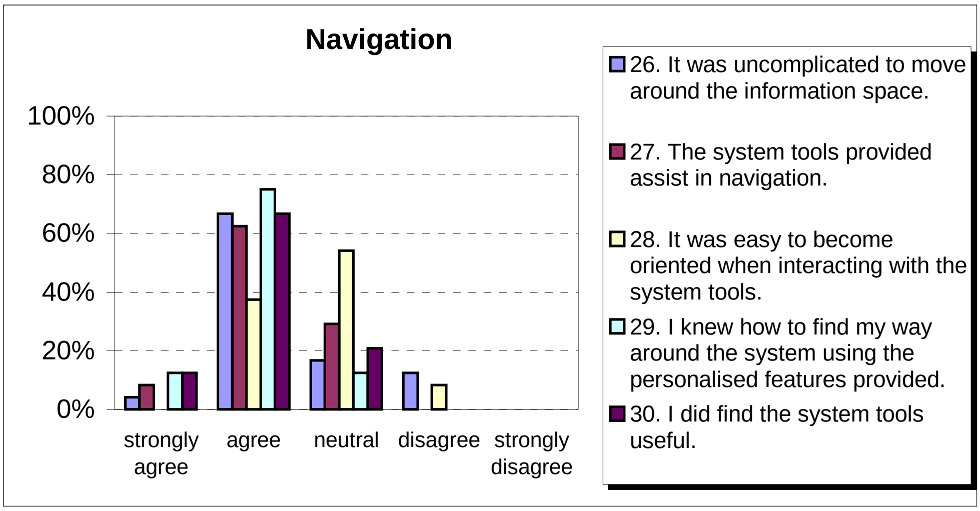


Figure 8-9: Subjective feedback on the 'Navigation' aspect of the system

Comprehension

The last five statements were designed to measure the degree to which users can understand the interaction with the system. Figure 8-10 summarises this finding.

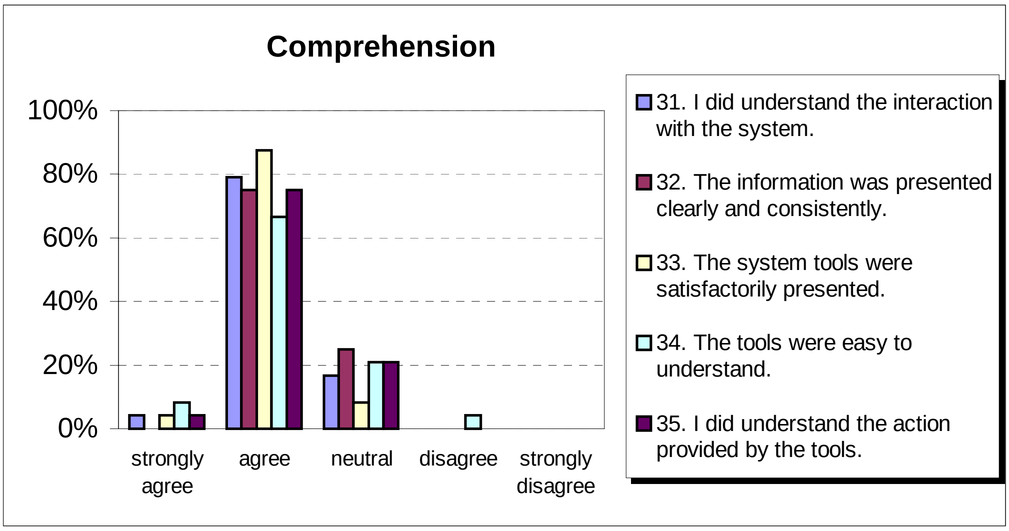


Figure 8-10: Subjective feedback on the 'Comprehension' aspect of the system

As can be seen in Figure 8-10, a significant majority of the users understood the interaction with the system (79% agreed, 17 neither agreed nor disagreed, and 4% strongly agreed). None of the respondents thought that the information was not presented clearly and consistently. Similarly, none of the users thought that the system tools were not presented satisfactorily, with 87.5% (twenty one users) agreed – the best score of this test – 8% (two users) neither agreed nor disagreed, and 4% (one user) strongly agreed. However, a minor percentage of disagreeing (4%, one user) was found in the statement about the tools being easy to understand.

Hypothesis 9:

H_1: The user-controlled adaptation provided by the MDL concept as applied to the IPNS is easy to understand.

H_0: The user-controlled adaptation provided by the MDL concept as applied to the IPNS is *not* easy to understand.

Based on the ‘one sample t-test’ as shown in Table 8-22, the null hypothesis for Hypothesis 9 was rejected ($t(23) = 15.755$, $p < 0.05$) indicating that the user-controlled adaptation provided by the MDL concept as applied in the IPNS was statistically easy to understand.

Scales	Statistical Results					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Comprehension	15.755	23	0.000	4.292	3.73	4.86

Table 8-22: Result produced by SPSS for the scale ‘Comprehension’

<u>Overall reactions to using the IPNS prototype and the tools provided</u>

This final question asked the users to give their responses for the overall reactions using the IPNS and its tools. Figure 8-11 shows the summary of the feedback on the overall reactions categorised by the number of users and Figure 8-12 demonstrates this result in percentages. As can be seen in the figures, the users gave very positive feedback and they agreed that the prototype system and the tools were *easy* and *satisfactory* (eighteen users, ~ 80%). Table 8-23 provides a summary of the statistical results for Experiment 3.

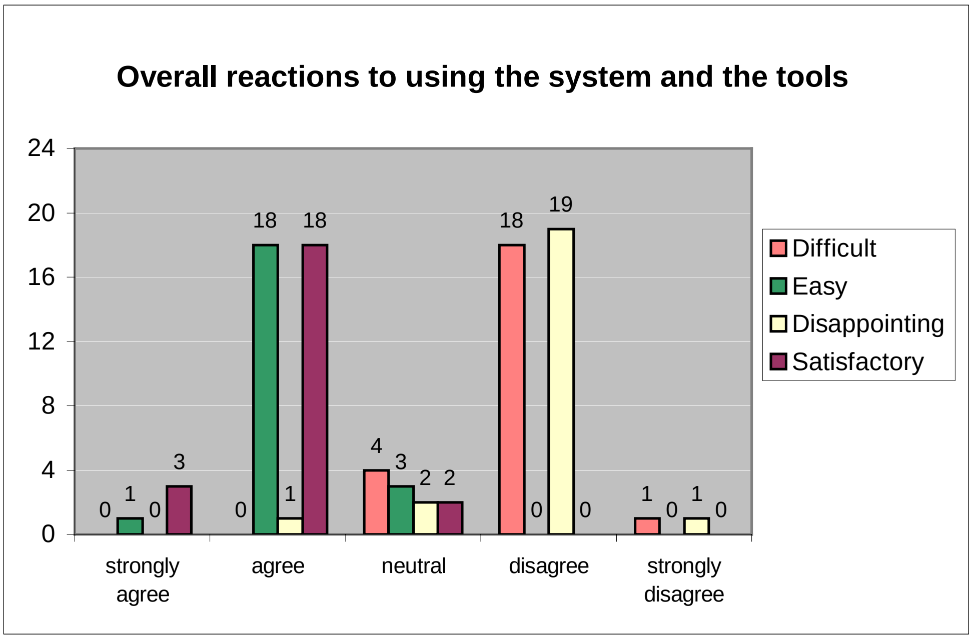


Figure 8-11: Subjective feedback on the 'Overall reactions using the system and the tools'

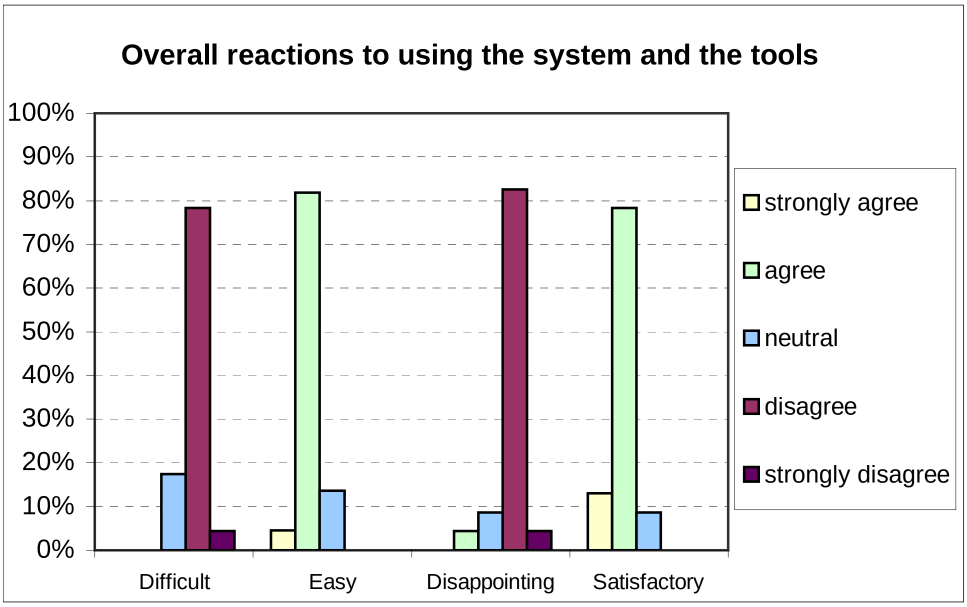


Figure 8-12: Percentage of the users' overall reactions using the system and the tools

Scales	Descriptive Statistics				One-sample *t*-test (95% Confidence Interval)
	N	Mean	Std. Deviation	Std. Error Mean	
Affect	24	3.71	2.255	0.460	t = 8.056, p (2-tailed) = 0.000**
Control	24	3.29	1.876	0.383	t = 8.595, p (2-tailed) = 0.000**
Efficiency	24	3.75	2.132	0.435	t = 8.619, p (2-tailed) = 0.000**
Helpfulness	24	3.13	2.290	0.467	t = 6.685, p (2-tailed) = 0.000**
Learnability	24	3.92	2.535	0.518	t = 7.568, p (2-tailed) = 0.000**
Navigation	24	3.63	1.689	0.345	t = 10.513, p (2-tailed) = 0.000**
Comprehension	24	4.29	1.334	0.272	t = 15.755, p (2-tailed) = 0.000**
Overall reactions					
• Easy	22	0.91	0.426	0.091	t = 10.000, p (2-tailed) = 0.000**
• Satisfactory	23	1.04	0.475	0.099	t = 10.543, p (2-tailed) = 0.000**

** Statistically significant at 95% Confidence Interval

Table 8-23: Summary of the statistical results for Experiment 3

8.4 Synopsis of Results

This section gives a summary of the results of the evaluation studies as presented earlier.

Heuristic evaluation: to report any strengths and weaknesses and the applicability of the user-controlled adaptation provided by the MDL concept as applied to the IPNS.

All of the expert evaluators agreed that the system did conform to the following heuristics: ‘Flexibility and efficiency of use’, ‘Easy to understand’, ‘Easy to remember’, ‘Pleasant to use’, and ‘Aesthetic and minimalist design’. Only one of the nine experts disagreed that the system conformed with the following heuristics: ‘Few errors’, ‘Consistency’, and ‘Match between the system and the real world’.

Empirical evaluation: to study the usefulness of the user-controlled adaptation provided by the MDL concept as applied in the IPNS protoype using ‘usability’ as evaluation criteria.

Experiment 1: to examine the effectiveness of the user-controlled adaptation provided by the MDL concept

Hypothesis 1, H_1 was accepted which indicated that the percentage of task completed was statistically improved by the set of links presented by the IPNS prototype in comparison to navigation without the presence of personalised features.

Experiment 2(a): to measure the efficiency of the user adaptation provided by the MDL concept

Hypothesis 2, H_0 was accepted indicating that the set of links presented did *not* increase the percentage of navigation completed in comparison to navigation without the presence of personalised features

Experiment 2(b): to study the subjective feedback if the users preferred the user-controlled adaptation provided by the MDL concept as applied in the IPNS prototype rather than non-personalised systems.

Hypothesis 3, H_1 was accepted, meaning that users *preferred* the user-controlled adaptation provided by the MDL concept as applied in IPNS than non-personalised systems.

Hypothesis 4, H_1 was accepted, indicating that the IPNS with the links presentation and personalisation tools was useful as it allowed the selection of links to be displayed based on users' preferences.

Hypothesis 5, H_1 was accepted. This indicated that users statistically confirmed that they had control over link presentation and personalisation in the IPNS.

Experiment 3: to study the users' opinions about the user-controlled adaptation provided by the MDL concept and the IPNS prototype.

Hypothesis 6, H_1 was accepted which indicated that users significantly liked interacting with the system.

Hypothesis 7, H_1 was accepted, meaning that the user adaptation provided by the MDL concept as applied in IPNS significantly allowed users to have control over links presentation and personalisation.

Hypothesis 8, H_1 was accepted indicating that the user-controlled adaptation provided by the MDL concept as applied in IPNS was significantly useful and helpful.

Hypothesis 9, H_1 was accepted which indicated that the user-controlled adaptation provided by the MDL concept as applied to the IPNS was easy to understand.

8.5 Discussion

This thesis has been undertaken with two research objectives in mind. With respect to the OH research, the work was aimed at providing a new application of the link augmentation technique by looking at a different view of representing a linkbase which stores link structures more effectively than traditional linkbases and solving the link overload problems caused by the conventional link augmentation technique. Secondly, regarding the AH research, this work attempted to deal with some of the AH criticisms that users do not understand or have control over adaptation behaviour of the system by faciliting user's control over personalisation.

The system implementation has established the affirmation that the MDL concept has presented a different view of representing a linkbase for link personalisation, which resulted in additional functionality to support the process of inserting additional links into the body of a document. The main emphasis of the evaluation study was therefore carefully chosen and designed to prove that by allowing users to have control over personalisation of links, IPNS would give the affordances the user expected from the adaptation. In this context, '*control*' is enabling users to see the working behaviours of the system, by means of the direct manipulation of the MDL and other linkbases. In doing this, redundant links are removed and therefore the link overload problem is reduced.

The studies were carried out to reflect the above mentioned principle of evaluation of IPNS. The heuristic evaluation reviewed by experts was purposely assigned to examine the strengths and weaknesses of the applicability of the user-controlled adaptation provided by the MDL concept as applied in the IPNS, and the empirical study was deliberately designed to study the usefulness of the user adaptation provided by the MDL concept using usability as the evaluation criteria. The experiments were intended to contribute these evaluation rationales by comparing the prototype system with non-personalised systems which served as control systems.

First, the result of the heuristic evaluation revealed that the user-controlled adaptation provided by the MDL concept and its IPNS prototype conformed to its requirements and most of its heuristics. There was no major error or problem with the integration of the MDL concept into the working prototype. The review has provided a rational indication that the user-controlled adaptation provided by the MDL concept was applicable, flexible and efficient, and far from being too abstract. However, no system is yet said to be perfect or error free. This inevitably encompasses our prototype system as well. Informative comments by the experts were elicited to give an insight into the implementation of the MDL concept on a bigger scale as an application.

Secondly, concerning the empirical study, the objective and subjective data were gathered and analysed by statistical techniques. The *IPNS prototype* was compared against other two systems serving as non-personalised systems ('control systems') – *system Non link* (i.e. system with no additional links given) and *system All links* (i.e. system with additional link insertion but users have no control over its presentation). The result for the first experiment has suggested that users could benefit from the *IPNS* in navigation, as the **percentage of task completed** was significantly improved by the set of links presented in comparison to navigation without the presence of personalised features (*system Non link*).

However, an insignificant difference between the IPNS and system All links in the second experiment was discovered, meaning that the set of links presented in IPNS did not increase the **percentage of navigation completed** (speed of navigation). This could possibly be due to one of the followings reasons:

- When a subject domain, like our domain, is not so large, the system with non-personalised link augmentation ('system with automatic-all-links insertion') might not yet appear problematic to some users. Some users commented that they preferred to see all links, hoping that the links would stand out as the answers themselves, or lead to some relevant piece of information. However, if the domain was larger and it was distributed across Web services environment, the problem with having no control over link presentation and personalisation might come into view more obviously, when every keyword could become a link.

- Another approach might have been to allocate users more tasks to perform in order to gain a significant result in capturing the percentage of navigation completed (speed of navigation), i.e. more terms or phrases needed to be assigned for users to search for (we asked users to look up only four keywords in the experiment conducted).
- The speed of navigation might not have been an appropriate dependent factor to measure in our studies. A better measurement might be to count the number of links the users used in finding the answers for the task. The more links given, the more likely that the user would need to spend time looking; hence, reducing their speed of navigation.

Having said this, the user-controlled adaptation provided by the MDL concept as applied in the IPNS allowed the presentation of links to be personalised (based on user's expertise dimensions and preference) with the options of having all links visible, only basic links or advanced links appearing, or no additional links inserting into a Web page at all. As a matter of fact, the function that the system All links provided was just a subset of all other functions the IPNS could perform.

With respect to the subjective comments, they were gained from the subjects mentally comparing the three systems (Experiment 2(b)), and from the attitude questionnaire which the users were requested to merely focus on the IPNS prototype and judged its conformity on the Likert scale in relation to the scales of evaluation (Experiment 3). Hypotheses proposed in the study and the two experiments were tested and statistical models were used in verifying the data. Based on the 'one-sample Chi-Square' test used for tables containing counts, with restrictions that Expected Value (E) should be five or above for the results of a χ^2 test to be valid (Diamond and Jefferies, 2001), the statistical results pointed that users significantly favoured the user-controlled adaptation provided by the MDL concept as applied in the IPNS to the non-personalised systems. Although there were a number of users who would rather use a non-personalised system (i.e. using 'table of contents') than using the tools provided in IPNS to locate the documents and perform required tasks due to its simplicity and straightforwardness, their fondness was not significant when comparing to the IPNS's users.

Similarly, the users reflected that using IPNS with the link presentation and personalisation tools was significantly useful as it allowed them to make selection of the links to be displayed, and statistically users felt they were in control of link presentation and personalisation in the IPNS.

Positive results were also obtained for the attitude questionnaire on SUMI scales and scales for evaluation of industrial hypermedia. Most of the statements were favourable, particularly the ‘Comprehension’ scale, where 87.5% (twenty one users) – ‘best result’- agreed that the systems tools were satisfactorily presented. Few users mentioned the general user interface matter (which was not in the scope of this work, but it certainly could be improved in the future for a more usable and user-friendly system) and the issue that ‘too many dimensions and too much setting’ might be cumbersome and cause users to be reluctant to use the system. This issue will be discussed futher in the next Chapter. With regard to the statistical analysis of data, the significant results pointed to the users enjoying interacting with the system, the user-controlled adaptation provided by the MDL concept as applied in the IPNS was useful and helpful, and the user adaptation provided by the MDL concept as applied in the prototype allowed users to have control over links presentation and personalisation. Overall reactions gained from the users were impressive and statistically easy and satisfactory.

On the whole, the studies revealed that the user-adaptation approach provided by the MDL concept facilitated the user’s control over personalisation of links. That is, IPNS enables the user to see the working behaviours of the system by means of the direct manipulation of the MDL and other linkbases. Through this adaptation process, irrelevant links are removed and therefore the user-controlled adaptation provided by the MDL concept can help to reduce the link overload problem.

8.6 Summary

This chapter has presented the evaluation that was conducted with the objective of examining the applicability and usefulness of the user-controlled adaptation provided by the MDL concept as applied in the IPNS prototype. The data was gathered objectively and subjectively, and analysed by means of statistical techniques. The results of this evaluation showed a significant level of acceptance from the ‘applicable’ and ‘useful’ aspect of the user-controlled adaptation provided by the MDL concept and its counterpart the IPNS prototype.

The following chapter provides a summary of the research undertaken in this thesis. The contributions this work has made as well as key research issues raised are particularly discussed. The chapter then concludes with the highlights of the possible directions this work could be continued.

Chapter 9 Conclusions and Future Work

This final chapter provides a summary of the work presented in this thesis, starting with the proposed MDL concept and its implementation, followed by the evaluation undertaken. The chapter then concludes, and hightlights the possible directions for future work.

9.1 Summary and Conclusion

This section summaries the major issues in relation to the MDL concept and its implementation.

9.1.1 MDL concept

This thesis has proposed the concept of a multi-dimensional linkbase (MDL) for links presentation and personalisation. Based on the link service approach and its link augmentation technique, MDL is a concept where set of links are created and stored in a single linkbase that contains links annotated with metadata, so that these links appeared as if they were existing in different contextual dimensions at once. These links signify dissimilar dimensions of expertise, and provide the contextual structure that enables and disables their visibility. Incorporating the MDL concept with a link server (acting as an query interface and supplying links on demand) enables links to be conditionally presented and personalised to the user, based on their individual profile. That is, the link server dynamically inserts supplementary links from the MDL into a Web page in relation to a user's expertise dimensions and levels of expertise in each dimension. Users who have different expertise with varied levels will therefore obtain dissimilar links presentation, and representations of links personalisation will be based on individual users.

Representation of links in the MDL, when used to support adaptive behaviour of the system, has been shown to solve some of the link overload problems caused by the traditional link augmentation technique. Traditionally, every keyword becomes a link and the links are presented to all users, which can result in the link overload problem. In the MDL approach, links are only offered and visible to the user based on their user model and levels of expertise in the expertise dimensions in MDL; hence reducing the 'too-many-additional links' syndrome. In addition, links from different contextual dimensions in MDL can be filtered by the culling process provided by the link server, which results in the corresponding links that match an individual user's context, hence alleviating the irrelevant links problem.

Another example to show the practicability of the MDL concept is that representing links within MDL makes possible multiple destinations from the same navigational link. Most systems with the link augmentation process base their link insertion on replacing individual keywords or phrases in the document (Bailey *et al.*, 2001), which results in one keyword becoming one hyperlink offering only a single destination. This common practice can lead to prolific linking. By contrast, the MDL concept enables the same keyword in the same context to become links pointing to different destinations, dependent on the user-chosen contextual dimensions of expertise in the linkbase.

For instance, a keyword 'dough' with the *Expertise* dimension as 'basic' and the *Language* dimension as 'English' would give a plain explanation that 'dough is a mixture of flour and liquid (water or milk) used to make bread and pastry and it may contain yeast or baking powder as leavening agent'(Bender and Bender, 1995). However, within the same context, the same keyword 'dough' as 'basic' in the *Expertise* dimension, but this time with the *Language* dimension as 'Spanish', would produce the link pointing to a different additional explanation that 'dough is *de la masa*' in Spanish (Morton and Morton, 1977).

9.1.2 MDL implementation

The work has presented the application of the MDL concept in a working prototype. The Inquiry-led Personalised Navigation System (IPNS) is a Web-based personalised system. Three linkbases were developed based on the application-dependent links classification: *Expertise MDL*, *Inquiry linkbase*, and *Glossary linkbase*. The Expertise MDL in particular comprised three dimensions of expertise, namely *Subject*, *Language*, and *Assessment Style*, whereby the *Subject* links, for example, were equipped with these options the user could choose for their links presentation: *'no link'*, *'basic links'*, *'advanced links'*, and *'all links'*. The Inquiry-led tools were designed to provide query interfaces between the Web application and the link server, and to make the personalisation of links possible. These tools served different function, but generally assisted the user in performing more exploratory navigational strategies. They could be used on demand and produced no effect when not in use.

9.1.3 MDL and Multiple Linkbases

The MDL concept has provided a different view of representing a linkbase for link presentation. Some situations make it impossible to employ multiple linkbases; for instance where there is a sub-dimension within a dimension, or where one link in the same linkbase can be annotated as a member of more than one group (e.g. being 'basic' in the expertise dimension, 'French' in the language dimension, and preferring 'visual' type of information in the style of presentation). Conversely, the MDL concept can efficiently support these situations and can store link structures more effectively than traditional linkbases. However, the author has not argued that multiple linkbases provide no benefit and should be totally disregarded. This is because at least one comprehensible benefit derived from creating multiple linkbases: it makes the maintainability of links possible. If all the links were kept in a single linkbase, the linkbase could be extremely large and unmanageable. A combination of integrating different MDLs would be an ideal solution – "multiple MDLs".

9.1.4 MDL and AH criticisms

Concerning the AH criticism that users are prevented from having control over the system's behaviour and users do not always understand why the system is adapting, the MDL concept, as applied in the IPNS prototype, provides users with a perception of the personalised aspect of the working system and facilitates users' control over personalisation of links more clearly and more easily (but not necessary better) than other adaptation approaches. The user can experiment with, and configure the system at runtime, to choose the optimal presentation to suit their expertise dimensions and preference, by either enabling or disabling the contextual dimensions. Finally, a better understanding of the adaptation process enables a user to make the system work more suitably for them, and hence also avoids the 'too-many-irrelevant-additional links' syndrome.

9.1.5 Evaluation

Evaluation of the MDL concept and the IPNS prototype was undertaken to prove the applicability of the user-controlled adaptation provided by the MDL concept and its usefulness. The results indicated that generally the expert evaluators and users accepted the user-adaptation approach provided by the MDL concept and its IPNS implementation. Largely, the evaluation studies confirmed that the MDL concept could support adaptive hypermedia by enabling the users to have control over personalisation of links in order to make adaptation work better for them, and hence could help the users to avoid the link overload problems caused by the open hypermedia's link augmentation technique.

9.1.6 Summary

To conclude, the MDL concept provides a potential alternative method of presenting several contextual hyperstructures in a single linkbase, and an additional functionality to support the link augmentation technique. Not only it is capable of providing a platform for open adaptive hypermedia, but it also increases the likelihood of users having a clearer and easier understanding of the adaptation process, and facilitates users' control over links presentation and personalisation; hence alleviating some link overload problems caused by conventional open hypermedia technique.

The author believes that the research objectives of this work have been achieved; that is, the work has presented a new application of the link augmentation technique (i.e. presenting a different view of representing a linkbase to support the link augmentation process, and providing additional functionality to solve some of the link overload problems), and dealt with one of the AH criticisms (i.e. facilitating users' control over personalisation of links). However, there have been research issues derived from this work and they require further exploration.

On the whole, the author has not suggested that the MDL concept will replace other ideas and concepts, but instead hopes that the MDL concept could be implemented to provide additional functionality to the link augmentation technique for any existing systems with provision of the link service approach, and to present an alternative to support adaptive hypermedia by making the adaptation process clearer and more easily to understand for the user.

9.2 Novelty of the research in this thesis

This thesis has presented the concept of a multi-dimensional linkbase (MDL) for links presentation and personalisation. It is a concept in which links are stored in a single linkbase, where they are annotated with metadata so that they appeared as if they were existing in different contextual dimensions at once. The provision of the contextual behaviour of the links conditions (i.e. enabling and disabling) the visibility of presentation and personalisation of links. The contributions this thesis has made in the field of open hypermedia and adaptive hypermedia are summarised as follows:

- The proposed concept of MDLs for links presentation and personalisation.
- Representation of an n-dimensional linkbase, furthering and advancing the work by Millard on contextual link structures in FOHM (Millard, 2000).
- The integration of the MDL concept into the development of an inquiry-led personalised navigation system (IPNS) prototype.
- Using taxonomy-based ontology in FOHM structures to provide semantic representation of concepts or associations of the subject domain to aid the process of querying for a concept.
- Statistical evidence showing the usefulness (effectiveness, efficiency and user satisfaction) in using the user-controlled adaptation provided by the MDL concept in a personalised presentation of links.

9.3 Future Work

This section discusses main research issues resulting from the evaluation and the possible exploration to deal with them. In addition, this section suggests some possibilities for the future work.

9.3.1 Research Issues

- **Classification of Links**

An extension to this work would be to look at how qualitatively the links in each dimension can be categorised into one dimension and not in another category. For example, the links in the *Expertise MDL* were categorised into three dimensions, i.e.

Subject, *Language*, and *Assessment* dimensions, and the *Subject links* applied the "Transformation Model" into their subclassification, which resulted in *Raw Material*, *Operations*, and *Output*. Each of these sub-dimensions provides four options for the user to choose, i.e. 'no links', 'basic links', 'advanced links', 'all links', for their presentation of links. Based on the current prototype, the 'rule of thumb' has been employed to classify the 'basic' and 'advanced' links. Therefore, in order to serve good quality links, the domain expert might still be required for the purpose of links categorisation.

- **The Annotation of Links**

One of the recommendations in the experiment was to differentiate links from different sub-dimensions, even though the use of different colours was already adopted to simply distinguish the Expertise links from the other two links (Inquiry and Glossary). To strengthen the MDL concept and its system implementation, the system developed should allow users toknow from which dimension in the MDLs the links are appearing, so that the users might be able to configure the system for the best personalisation of links to suit their expertise and preference. The possible techniques that might serve this purpose include a number of link annotation techniques such as colouring links from different dimensions distinctively; the concept as applied in 'Fluid links' (Zellweger *et al*., 1998) i.e. annotating links with additional information about the destination page, whereby the annotations are added below a link anchor after the user moves the mouse over it (Tsandilas and schraefel, 2003); adapting the font size of the links (Tsandilas and schraefel, 2003); and using small icons to symbolise link types (Weinreich and Lamersdorf, 2000).

In addition, Weinreich and Lamersdorf (2000) provided a short survey of methods to present link types, which can be firmly implemented with the MDL concept, for instance, *link colour*, *mouse pointer* (i.e. the pointer changes according to the link type when it hovers over a link), and *popups* or *rollovers* (i.e. small floating windows appearing next to the mouse cursor when moving over a link).

- **Advanced Text Processing or Information Retrieval Techniques**

Other research issues raised in the experiment involve looking into more advanced text processing and parsing techniques. First, some users pointed out that they did not like seeing repeated words. In interviews with the users after the evaluation, it transpires that they thought it would be more useful and less distracting if they could be provided with the option asking them if they wanted to see the same keyword presented and appeared as links more than once. For instance, the word 'gluten' coming from the *Subject* dimension and the *Output* sub-dimension, would appear as links everytime the user chooses the option 'basic links' for the *Output* sub-dimension. As a matter of fact, every paragraph containing the word 'gluten' would become a link to its additional explanation. However, when the user selects the option 'advanced links' for the same sub-dimension, the word 'gluten' would no longer be a link. Nevertheless, their concern was that they wished to only see the word 'gluten' as a link once, or at least they would have an option if they wanted to see the same word as links more than once or not.

- **Adaptability to Adaptivity**

Lastly, a few users pointed out that it might be cumbersome in a bigger hyperspace if there were too many dimensions and sub-dimensions for them to make selection for the presentation of links. This could dissuade the users from configuring and making use of the system. As a consequence, the shift from 'personalisation or adaptability' to 'adaptivity' might discontinue the argument. That is, instead of replacing the previous user selection on link presentation with a new selection, as now, these past records could possibly be logged to refine the degree of accuracy for providing satisfactory corresponding links in relation to each expertise dimension. The system could automatically apply this knowledge to provide augmented links. In other words, some kind of inference engine or mechanism is required.

One possible approach might be to use an information retrieval technique, such as *Term Frequency Inverse Document Frequency* (TFIDF), to calculate the frequency of the selected option of each expertise dimension by requesting the users perform some tasks and set this weight against the statistical frequency of the options occuring in a random set of sample documents (Joachims *et al.*, 1997).

However, we need to be sure that the adaptivity provided by the system will not overshallow the 'free-form' approach provided by the OH research. As Conlan (2003) also pinpointed, the balancing control made available to users and the transparency of the adaptivity need to be considered, as these issues can introduce design arguments.

9.3.2 Future Research Directions

In addition to the research issues which arose in the experiment, the following section recommends the future research direction this work could take.

- **Authoring Tools Development**

The authoring tools could reduce the authoring effort for the system developer in links creation in MDLs. For instance, a *concept graph editor* could be implemented to provide a visual view of the interconnection between concepts in the domain ontology. Rather than a user seeing the result of his search for a particular topic of interest in a textual representation, as shown in Figure 9-1, the user would be offered a visual illustration. This would ideally help users understand how each of the concepts related to another concept better. Furthermore, it would also diminish the authoring attempt for the system developer in adding new items, deleting, drawing and viewing the semantic relationships of all concepts. Another vision is to implement this idea in all MDLs, so that the user could see how links reside in each contextual dimension in graphical form. This would assist the user in deciding on which contextual links in the MDLs they are seeking.

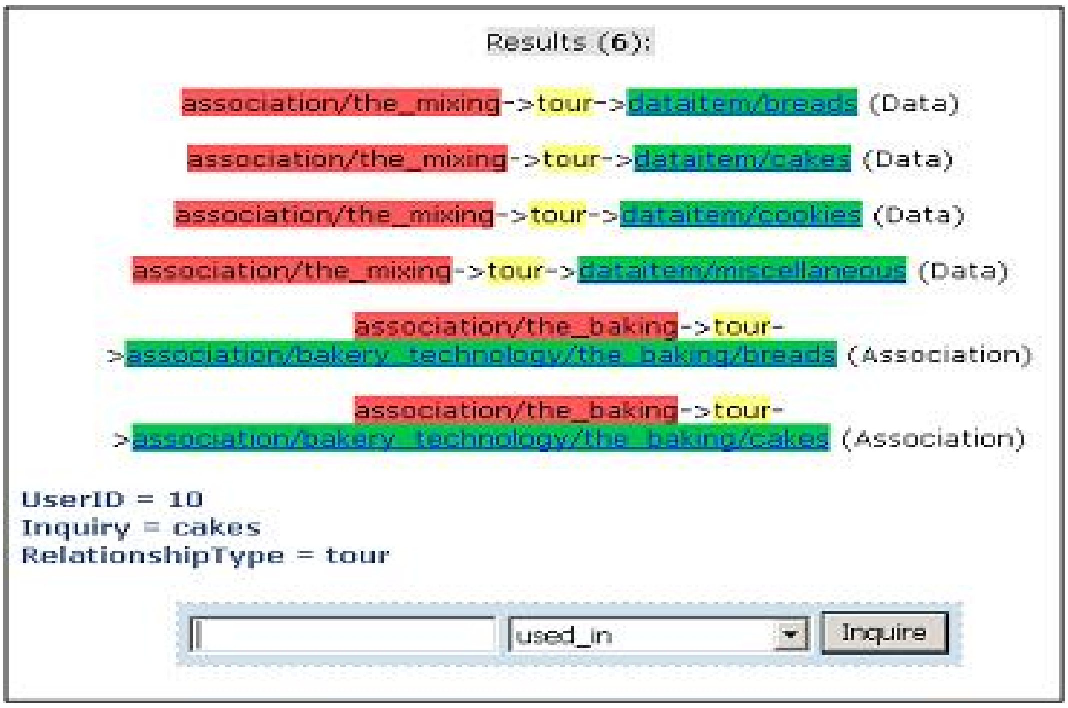


Figure 9-1: The current representation of a user's search result for a topic in the ontology

- **User Interface Enhancement**

One of the future works could be looking at how the user interface could be improved so that the implementation of the MDL concept could be more usable and user-friendly, for instance, the use of 'mouse click' instead of users highlighting a keyword or phrase for following links.

- **The Use of Ontologies**

The use of ontologies requires further exploration. At present, the author employed a semantic network to represent the interconnection between concepts (associations) of the subject domain in the form of a 'taxonomy-based' ontology, whereby a concept relates to another concept by means of established relationship type. New relationship types for use in FOHM were created. This results in the provision of the *Inquiry* links interface to serve links matching a user's search for a topic or concept of interest.

- **Integrating into the Web Service Environment**

Despite the MDL concept and its IPNS application was implemented in a domain specific; one of the possible research directions this work could take is to continue its development in a Web Service environment to faciliate shareability and reusability issues. Figure 9-2 demonstrates the transformation of the MDL concept and the extension of its operational components in a Web Service environment. It describes how these functional services could work in collaboration, in operational order. Each layer represents the communication between the services from the outermost (the Link Service) to the innermost (systems that could benefit from the implementation). The *Presentation layer* deals with the links presentation to a user via a Web Browser. *The Data Extraction layer* concerns capturing a user trail (e.g. lists of user-related information such as user model, domain model, terms or concepts users are interested in, etc.). The *Adaptation layer* involves link query, rules and inferencing mechanism, link augmentation. The *Link Service* layer is where the link processors reside (FOHM-based structures in MDLs, Auld Linky, and Link Editor).

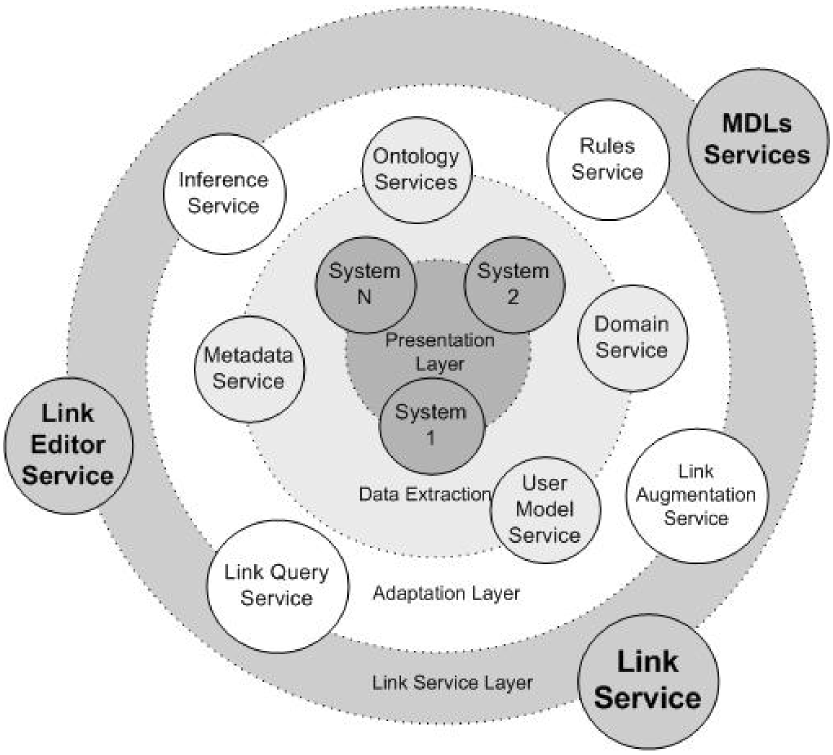


Figure 9-2: Incorporating the MDL concept into a Web Service environment

- **Incorporating the MDL concept to support Personalised Web Learning Environment**

The learning environment could rightly gain benefit from the MDL concept. Considering different expertise as diverse contextual dimensions would allow the learner to be presented with personalised links or contents particularly right for their levels of expertise. For instance, one of the expertise dimensions could be *Learning Style* (e.g. visual, auditory, or tangible), or *Pedagogy* (e.g. instructional design, inquiry-based learning, etc.), where the student could be provided with the contents and links according to their learning style and preference. With the implementation of the rules or inference engine, the system's decision-making can be automatic, based on the result of the individual user model.

In addition, the user's knowledge of each of the concepts in the domain model needs to be kept (De Bra *et al*., 2004) and in order to assess their knowledge, the user would be required to accomplish some forms of assessment, where the result could indicate the learner's level of understanding (i.e. learning performance).

- **New Approach on Evaluation**

One aspect of future work is to extend the evaluation study to a larger scale. A new approach could be introduced. For instance, once the MDL implementation incorporates with the inference engine, the benefits of layered evaluation of adaptive applications and services (Brusilovsky *et al.*, 2001) could be experienced, i.e. the evaluation can be performed at two distinct layers – *interaction assessment* and *adaption decision-making*. In addition, since not only the quantity of links, but also the quality aspect of the links, are of the author's interests; other quantitative evaluation methodologies, as well as qualitative methodologies, need to be explored. As Gena (2005) described and proposed, less explored methodologies such as "Grounded theory" needs thorough investigation.

In addition, current evaluation studies produce results for their own particular system; however, as Weibelzahl (2005) remarked, universal criteria would allow integrating the results between different systems in a wider perspective.

9.4 Concluding remarks

This work has presented the MDL concept and applicability of its implementation. It has also shaped the opportunity for this work to be undertaken in the future research. Moving towards the Web Services and the Semantic Web will enable the proposed system, OH and AH systems in general, to become more reusable and shareable. The two fields have provided, and positively changed, the way information can be presented to the user based on their background, interest and knowledge. In the future, users will surely benefit more and more from the extensive research and everything they do on the Web will be personalised in some way, if not all personalisation. Nevertheless, the author believes that the day will come when all the systems can be human-like and even as intelligent.

Appendix A. Heuristic Evaluation

I) Introduction

<table>
<tr>
<td>Heuristic Evaluation

1</td>
<td>Introduction

The separation of links from documents (the Open Hypermedia fundamental) enables links to be created, added, or modified without any effect on the original document, and that despite the documents being modified or moved around the links would still function (Bailey et al., 2001).

Some problems with traditional links augmentation technique (a technique whereby links are inserted directly into the document) are that

• Every keyword can become a link, or there are too many links inserted into the document (‘Prolific linking’, Carr et al., 2002).
• Situations when links fail to present in the right document’s context (‘out of context’ or irrelevant links’) (El-Beltagy et al., 2002).

2</td>
</tr>
<tr>
<td>Adaptive Hypermedia techniques allow information (contents and links) to be personalised and adapted.

However, one of the main criticisms of the adaptive systems is that users are prevented from seeing the system’s behaviour (Tsandilas and schraefel, 2004), and users have no control over the presentation of contents and links.

3</td>
<td>Research Objectives

• To provide a new application of the link augmentation technique by
– presenting a different view of representing a linkbase.
– solving some of the problems caused by the traditional open hypermedia technique (‘Link Augmentation’) that too many links are dynamically inserted into the document (prolific linking and irrelevant links).
• To deal with one of the criticisms of adaptive hypermedia that users are not allowed to have control over the personalisation and adaptation.

4</td>
</tr>
</table>

The MDL Concept In a domain where there are many categories of users such as novices, beginners, or advanced users (and some stages in between) within a given context, or when there are many expertise dimensions required in the subject domain, the MDL concept can be beneficial. For instance, a user who is a skilled English historian but has no expertise in Asian history needs a different set of links presentation from a user who might be an Asian historian but has limited knowledge about English history. 5	The MDL concept is *a notion that describes a single linkbase that contains links annotated with metadata* . These different sets of links in the linkbase are treated as different dimensions of expertise and are encoded to condition the visibility of links and are dynamically inserted into the webpage when selected. If no links are chosen, the user will only see the common (static) structural links to navigate between web pages. So, for instance, one link could be annotated as a member of the expert group while another in the same linkbase could be annotated as a member of novice group. At the same time users are provided with control over the presentation and personalisation of links. 6
Objectives of the Reviews To report any strengths and weaknesses and <u>the applicability of the user-controlled adaptation provided by the MDL concept</u>, as a possible additional functionality to solve some of the problems with links overloads and to allow the user control over the links presentation and personalisation. 7	*The concept of MDL was applied and implemented in the development of the prototype system, called Inquiry-led Personalised Navigation System (IPNS).* There are three tools which allow the integration of the MDL concept and links presentation and personalisation. • *Tool 1*: *Personalised Links Assistant* interface – this tool allows users to select the links to be displayed, based on their background and preference. 8
– Based on the concept that users have different levels of expertise and background, hence they should not have to see the links that they don’t want to see. – Another example, some users do not want to see all the links that they already know the meanings of, and they only want to see the links that correspond to their expertise levels, i.e. basic or beginner, advanced, etc.	• *Tool 2: **Inquiry Links*** – used to search for Concepts in the subject domain. This tool uses the same principle as the search engine but it is NOT a search engine. It will only display results when the searching word is in our concept relationships or domain ontology. • *Tool 3: **Follow links*** – used to search for a word we want to know if there are any links related from this searched

– This concept also allows one given keyword to become links for an individual person, but not for another person, or some same keyword can become a link pointing to different destination based on the skill and preference of users. For instance, a keyword ‘wheat’, when users select *Language* as English, ‘wheat’ will be a link to its description. However, if the user selects *Language* as Latin, this same word ‘wheat’ will point to the its name in Latin.	word. If there are, then it will know the links. Users need to highlight the word they are looking for and click the **Select Text** button at the end of each web page.
9	10

II) Heuristic Evaluation Form

: *To report any strengths and weaknesses and the* ***applicability of the user-controlled adaptation provided by the MDL concept*** as applied to the development of an Inquiry-led Personalised Navigation System (IPNS) prototype.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Flexibility and Efficiency of use (the system should be able to deliver its functionality (i.e. the presented links are rightly functional and acceptable) either to experienced or inexperienced users and allow users to perform their task)					
Comments:					
Easy to comprehend (the user should find it easy to understand the interaction with the system i.e. interacting the links interfaces is easy to understand)					
Comments:					
Easy to remember (the user should not have to remember instructions in order to interact with the system)					
Comments:					
Pleasant to use (the system should provide user-friendly interface and the user should enjoy interacting with the system)					
Comments:					
User control and freedom (the user should be able to choose the system functions (i.e. link presentations and personalisation) and have control and freedom in interacting with the system)					
Comments:					

Few errors (the system should be error-free or generate few errors i.e. the system should deliver links correctly according to its function and interface)					
Comments:					
Consistency (the use of language and format of the system should be consistent)					
Comments:					
Aesthetic and minimalist design (the system should provide a modest design and not contain irrelevant information)					
Comments:					
Match between the system and the real world (the system should speak user's language rather than system-oriented terms)					
Comments:					
Other Comments e.g. *are there any other potential usability problems with links presentation and personalisation?*; *can different sets of links in an MDL be tagged and presented to users based on their use model?*					

Appendix B. Empirical Evaluation

I) Introduction

User's Evaluation 1	**Introduction** **In this experiment, there are 3 systems:** •**System 1 –** normal Website •**System 2 –** system + all additional links inserted into a Web page but users cannot change the setting in relation to their user profile (i.e. background knowledge, preference, etc.) •**System 3 –** system + additional links inserted in to a web page whereby the user can select how they want links to be presented with the options: 'all links', 'no links', 'basic links', or 'advanced links'. This system comes with tools, which might help users to control links presentation and personalisation. 2

We want to compare

- **System 1** (no additional links) + **System 3** (additional links whereby the users can choose), and

- **System 2** (additional links but users cannot select links to be displayed based on their user preference) and **System 3** (additional links + users can choose how the links to be displayed).

We want to examine if *allowing users to control the links presentation, which the user can select links to be displayed with four options: no links, all links, basic links, or advanced links, and where users can select the setting back and fourth as they wish, is more useful than the system when the user has to see all the links presented without being able to change them.*

3

To Compare

We need to have factors to compare each system against each other; in this case, we use **the time to finish tasks** and **speed of navigation**.

Therefore, please do not worry if you cannot finish the questions. They are there to see if you can find the answers for them, we are NOT testing your understanding of the subject domain in any way.

4

In **System 3 – IPNS**
(The system with additional links whereby the user can select the setting at their preferences).

There are 3 tools in the System 3.

- *Tool 1*: ***Personalised Links Assistant***
  – this tool allows users to select the links to be displayed based on their background and preference.

  – Based on the concept that users have different levels of expertise and background, hence they should not have to see the links that they don't want to see. For instance, a user who is a skilled English chef but does not anything about Thai cooking should see the different links from the user who is a Thai chef but has no expertise in English cooking. Users should be able to select the links presentation and personalisation based on his or her skill.

5

– Another example, some users do not want to see all the links that they already know the meanings of, and they only want to see the links that correspond to their expertise levels, i.e. basic or beginner, advanced, etc.

–This concept also allows a given keyword to become links for an individual person, but not for another person, or the same keyword to become a link pointing to different destination based on the skill and preference of users. For instance, a keyword **wheat**, when the user selects **Language** as **English**, **wheat** will be a link to its description. However, if the user selects Language as Latin, this same word 'wheat' will point to the its name in Latin.

6

•*Tool 2:* ***Inquiry Links*** – used to search for Concepts in the subject domain. It uses the same principle as the search engine but it is NOT a search engine. It will only display results when the searching word is in our concept relationships or domain ontology. •*Tool 3:* ***Follow links*** – used to search for a word we want to know if there are any links related from this searched word. If there are, then it will know the links. Users need to highlight the word they are looking for and click the **Select Text** button at the end of each web page. 7	

II) Pre-Evaluation Questionnaire

User ID ____________

Date ___________

Please select the following answers best describing you.

Q1: What is your age group?

18-25 26-35 36-45 46-65 66+

Q2: What is your gender?

Male Female

Q3: Which course are you taking?

- ○ Computer science/IT or IS related
- ○ Management
- ○ Other science or engineering
- ○ Others please specify ________________________

Q4: Which one of the followings best describes how you use computers?

- ○ Internet/emails
- ○ Study/Work
- ○ Others please specify ________________________

Q5: How often do you use computers for the purpose in Q4?

- ○ None
- ○ Hardly
- ○ Usually
- ○ Often
- ○ Always

Thank you for taking your time completing this survey.

You can now begin the evaluation.

III) Tasks for Group 2.1

a) Task 1 for Group 2.1

This task is to investigate the effectiveness of the MDL concept as applied in IPNS.

1. Register and Log in to the prototype system (system 1)
   Username ________
   Password ________

2. Explore the Website generally (not more than 5 minutes).

3. Use the website (i.e. table of contents) to answer the following questions, or as many as possible. Please do not forget to write down the time when you start and are done. **(*15 minutes*)**.

Time start ________ (e.g. 09:09 am)

Q1: Find out *what carbohydrates are and what their categorisation is* (in **Carbohydrates**). ____

____

Q2: Which of the following answers describes *the meaning of 'gelatinization'*? (in **Carbohydrates** > **Starches**).
a) The process when proteins are hydrolysed and broken into several amino acids.
b) The process when starch granules take up water and starts to swallow and forms gel.
c) The process when bacteria has infected food and caused food poisoning.
d) None
e) I am not sure

Q3: *Rope* is caused by spore-foaming bacteria (B. *subtilis* and B. *mesentericus*) occurring on wheat and hence in flour. The spores can survive baking and then are present in the bread which then leads to the formation of discoloration, fine silky threads when slices of the crumb are pulled apart, and a characteristic fruity odour (in **Microorganisms** > **Bacteria**) Yes / No

Q4: *Chlorination* is the treatment found in which one of the following (in **Bakery Ingredients**)
a) Wheat flour
b) Sugar
c) Dairy products
d) None
e) I am not sure

Q5: One of *the functions of milk / dairy products in breads* is to give structure (in **Baking Ingredients** > **Milk and Other Dairy Products**). Yes / No

Q6: What is *gluten*? and please name *the two essential compounds* involved in its formation (in **Proteins**).

____

____

Q7: Name the *classification of cookies or biscuits* and what is *the difference between macaroons and ladyfingers.* (in **Bakery Products** > **Cookies**).

____

____

Q8: Cakes *are classified based on* ***ingredients*** *and* ***mixing methods*** into batter-type and foam-type (in **Cakes**). Yes / No

Q9: What is *foreign materials control*? What do they do in bakery technologies? (in **Bakery Sanitation**).

____

____

Time finish __________ (i.e. 10:09 am)

Once you are completed, answer the following questions

i) I found the table of contents assisted me in finding information required.

Agree	Not sure	Disagree

Any comments?

____

ii) I found the tables of contents helpful.

Agree	Not sure	Disagree

Any comments?

____

Thank you very much for your time and kind co-operation.
All information given will be kept confidentially.

b) Task 2 for Group 2.1

This task is to examine the efficiency of the MDL concept as applied in IPNS in comparison to the controlled systems.

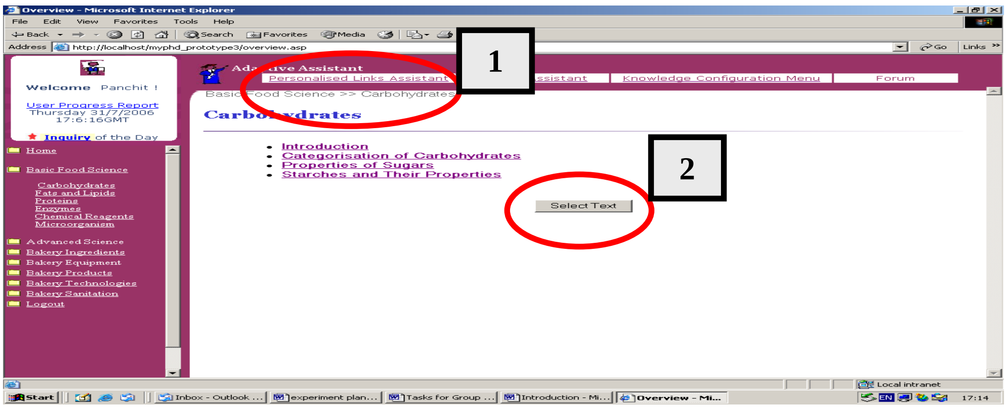
1. Please *write down your username* and *password* as this information will be used for the control systems.

   Username ________

   Password ________

2. *Call the instructor* to proceed to the experiment for the prototype system (**system 3**)

3. In the system 3 prototype, please use one of the following tools to answer all questions below, or as many as possible. Please do not forget to write down the start and finish time (***15 minutes***).



1- *Personalised Links Interface* – an interface providing users with additional links dynamically inserted into a page based on users' preference and background. The user has the options of 'no links', 'basic', 'advanced', and 'all links'. To **use the tool**, **select the options,** as shown below, and **see the additional links** each option produces in the webpage and look for the answers for the questions. The user can select and reselect as desired .

2- *Follow Links Interface* – an interface that allows users to highlight a keyword and query for additional links. To **use the tools**, **highlight the word** you want to know, as shown below; select the Select Text button at the bottom of the page; see if there is any link associated with the keyword; and answer the questions.

Time start ________ (e.g. 09:09 am)

Q3.1: Find out *what carbohydrates are and what their categorisation is* (in **Carbohydrates**).

____

Q3.2: Which of the following answers describes *the meaning of 'gelatinization'*? (in **Carbohydrates** > **Starches**).

a) The process when proteins are hydrolysed and broken into several amino acids.
b) The process when starch granules take up water and starts to swallow and forms gel.
c) The process when bacteria has infected food and causes food poisoning.
d) None
e) I am not sure

Q3.3: *Rope* is caused by spore-forming bacteria (B. *subtilis* and B. *mesentericus*) occurring on wheat and hence in flour. The spores can survive baking and then are present in the bread which then leads to the formation of discoloration, fine silky threads when slices of the crumb are pulled apart, and a characteristic fruity odour (in **<u>Microorganisms</u>** > **<u>Bacteria</u>**) Yes / No

Q3.4: *Chlorination* is the treatment found in which one of the following (in **<u>Bakery Ingredients</u>**)
a) Wheat flour
b) Sugar
c) Dairy products
d) None
e) I am not sure

Q3.5: One of *the functions of milk / dairy products in breads* is to give structure (in **<u>Baking Ingredients</u>** > **<u>Milk and Other Dairy Products</u>**). Yes / No

Q3.6: What is *gluten*? and please name *the two essential compounds* involved in its formation (in **<u>Proteins</u>**).

____

Q3.7: Name the *classification of cookies or biscuits* and what is *the difference between macaroons and ladyfingers.* (in **<u>Bakery Products</u>** > **<u>Cookies</u>**).

____

Q3.8: Cakes *are classified based on* ***ingredients*** *and* ***mixing methods*** into batter-type and foam-type (in **<u>Cakes</u>**). Yes / No

Q3.9: What is *foreign materials control*? What do they do in bakery technologies? (in **<u>Bakery Sanitation</u>**).

____

Time finish ____________ (e.g. 10:09 am)

4. Please call the instructor to proceed to the experiment for **system 2**.

5. In system 2, please locate *the following terms* and *circle* them if you have found them, and do not forget to write down the start and finish time. Do not worry if you cannot finish within the required time (***5 minutes***).

Time start ________ (e.g. 09:09 am)

Crumb (in **Basic Food Science** > **Carbohydrates** > **Starches and Their Properties**)
Gluten (in **Basic Food Science** > **Proteins > Gluten as a Protein**)
Caramel (in **Bakery Ingredients** > **Sugars and Syrups** > **Functions of Sugars in Bakery Products**)
Rope (in **Basic Food Science** > **Microorganism** > **Bacteria** > **Roles of Bacteria**)

Time finish ________ (e.g. 10:09 am)

6. At the *Table of Contents*, please select **Basic Food Science** > **Proteins > Gluten as a Protein.**
7. Please *consider* and *count* the number of links approxiately. ________

8. Please call the instructor to proceed to the experiment for system 3.

9. In system 3, please select the *P**ersonalised Links Assistant interface*** as ***'all links'.***

10. Please *consider* and *count* the number of links approxiately. ________

11. Select the *Personalised Links Assistant interface* and the *Expertise Dimensions* as *'basic'* and ***Language*** as ***'English'***.

12. Please *consider* and *count* the number of links approxiately**.** ________

13. *Concentrate* on the link for the word ***'dough'*** and *follow the link* to its explanation.

14. *Reselect* the ***Personalised Links Assistant interface*** > **the *Expertise Dimensions*** as ***'basic'*** and ***Language*** as ***'Spanish'.***

15. *Concentrate* again on the link for the word ***'dough'*** and *follow the link* to its explanation. Describe what you see. ________________________

16. This time, please *select* the ***Personalised Links Assistant interface*** and **the *Expertise Dimensions*** as ***'advanced*** (the ***Language*** is still chosen as '***Spanish'***).

17. Consider the word ***'dough'*** again and count the number of links approximately. .

18. What are your opinions? Select the statement that is most appropriate for you.

i) I found the system with *Personalised Links Presentation and Personalisation tools* (**as in system 3**) helped me find the document.

Agree	Not sure	Disagree

Any comments?

____

ii) I found that there were too many links inserted into the document in the '*system with all additional links but no control over links presentation* (**system 2**) and some of these links were what I had already known.

Agree	Not sure	Disagree

Any comments?

____

iii) I found the '*system with all additional links but no control over links presentation'* (**system 2**) useful.

Agree	Not sure	Disagree

Any comments?

____

iv) I found the 'system with *links presentation and personalisation'* (**system 3**) were useful as it allowed me to select the links to be displayed ('*all links*', '*basic*', or '*advanced*'), or not to be presented (*'no links'*).

Agree	Not sure	Disagree

Any comments?

____

v) I found *the system with the Links Presentation and Personalisation tools* (**system 3**) enabled me to have the control over the links presentation and personalisation, that is, I could select the links to be presented.

Agree	Not sure	Disagree

Any comments?

____

vi) I think *the MDL concept* and the *Personalised Links Assistant* were useful, as they allowed the same keyword to become different links based on the user's selection (e.g. '*wheat*' can be a link pointing to its definition, or a link pointing to the origin in Latin, depending on the user's selection of links presentation).

Agree	Not sure	Disagree

Any comments?

____

vii) I think *the MDL concept* and the *Personalised Links Assistant* could solve some of the problems of too many additional links being inserted into the document, when these links might not be of concern, not only in this specific domain, but also in bigger hyperspace.

Agree	Not sure	Disagree

Any comments?

____

viii) I think *the Links Presentation and Personalisation* interfaces were user-friendly and easy to use.

Agree	Not sure	Disagree

Any comments?

____

ix) I would prefer to use the following system to locate the documents and perform all required tasks in the future:

○ Table of contents (**system 1**)
○ System *with additional links but no control over link presentation* (**system 2**)
○ System *with links presentation and personalisation* (**system 3**)

Any comments?

____

x) I would prefer to use the following system for *links presentation*:

○ System *with additional links but no control over link presentation* (**system 2**)
○ System *with links presentation and personalisation* (**system 3**)
○ None

Any comments?

____

Thank you very much for your time and kind co-operation.
All information given will be kept confidentially

IV) Tasks for Group 2.2

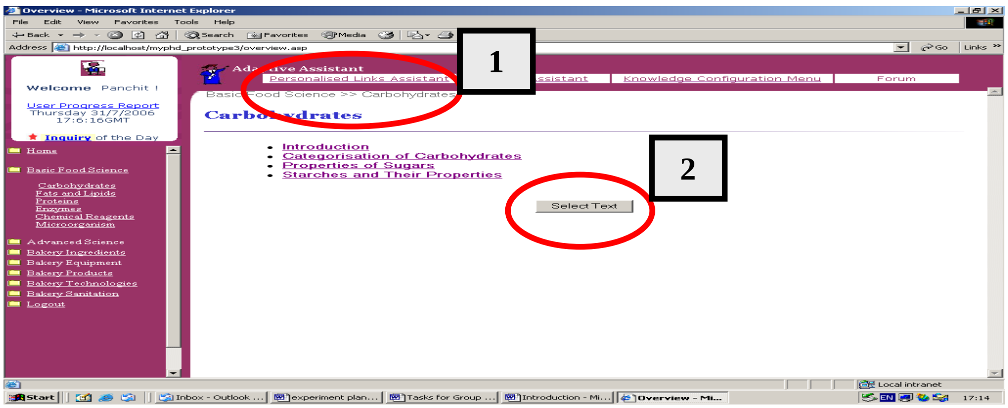
a) Task 1 for Group 2.2

This task is to investigate the effectiveness of the MDL concept as applied in IPNS.

1. Register and Log in to the prototype system (system 1)
   Username ________
   Password ________

2. Explore the Website generally (not more than 5 minutes).

3. Please use one of the provided tools to answer all questions below, or as many as possible, and do not forget to write down the start and finish time you attempted the questions **(*15 minutes*)**.



1- *Personalised Links Interface* – an interface providing users with additional links dynamically inserted into a page based on users' preference and background. The user has the options of 'no links', 'basic', 'advanced', and 'all links'. To **use the tool**, **select the options,** as shown below, and **see the additional links** each option produces in the webpage and look for the answers for the questions. The user can select and reselect as desired.

2- *Follow Links Interface* – an interface that allows users to highlight a keyword and query for additional links. To **use the tools**, **highlight the word** you want to know, as shown below; select the Select Text button at the bottom of the page; see if there is any link associated with the keyword; and answer the questions.

Time start ________ (e.g. 09:09 am)

Q1: Find out *what carbohydrates are and what their categorisation is* (in **<u>Carbohydrates</u>**).

____

Q2: Which of the following answers describes *the meaning of 'gelatinization'*? (in **<u>Carbohydrates</u>** > **<u>Starches</u>**).

a) The process when proteins are hydrolysed and broken into several amino acids.
b) The process when starch granules take up water and start to swell?and form a gel.
c) The process when bacteria has infected food and causes food poisoning.
d) None
e) I am not sure

Q3: *Rope* is caused by spore-forming bacteria (B. *subtilis* and B. *mesentericus*) occurring on wheat and hence in flour. The spores can survive baking and then are present in the bread which then leads to the formation of discoloration, fine silky threads when slices of the crumb are pulled apart, and a characteristic fruity odour (in **Microorganisms** > **Bacteria**) Yes / No

Q4: *Chlorination* is the treatment found in which one of the following (in **Bakery Ingredients**)
f) Wheat flour
g) Sugar
h) Dairy products
i) None
j) I am not sure

Q5: One of *the functions of milk / dairy products in breads* is to give structure (in **Baking Ingredients** > **Milk and Other Dairy Products**). Yes / No

Q6: What is *gluten*? and please name *the two essential compounds* involved in its formation (in **Proteins**).

____

Q7: Name the *classification of cookies or biscuits* and what is *the difference between macaroons and ladyfingers.* (in **Bakery Products** > **Cookies**).

____

Q8: Cakes *are classified based on* ***ingredients*** *and* ***mixing methods*** into batter-type and foam-type (in **Cakes**). Yes / No

Q9: What is *foreign materials control*? What do they do in bakery technologies? (in **Bakery Sanitation**).

____

Time finish _________ (e.g. 10:09 am)

Once you have completed, answer the following questions

i) I found the *Personalised Links Assistant* assisted me in finding information required.

Agree	Not sure	Disagree

Any comments?

____

ii) I found *the Follow Links interface* assisted me in finding information required.

Agree	Not sure	Disagree

Any comments?

____

iii) I found the *Links presentation and personalisation* tools helpful.

Agree	Not sure	Disagree

Any comments?

____

Thank you very much for your time and kind co-operation.
All information given will be kept confidentially

b) Task 2 for Group 2.2

This task is to examine the efficiency of the MDL concept as applied in IPNS in comparison to the controlled systems.

1. Please *write down your username* and *password*, as this information will be used for the control systems.

   Username ________
   Password ________

2. *Call the instructor* to proceed to the experiment for the prototype system (**system 1**).

3. In the system 1 prototype, please use ***'Table of Contents'*** to answer all questions below, or as many as possible. Please do not forget to write down the start and finish time. Do not worry if you cannot finish them (***15 minutes***).

Time start ________ (e.g. 09:09 am)

Q3.1: Find out *what carbohydrates are and what their categorisation is* (in **Carbohydrates**).

____

Q3.2: Which of the following answers describes *the meaning of 'gelatinization'*? (in **Carbohydrates** > **Starches**).
a) The process when proteins are hydrolysed and broken into several amino acids.
b) The process when starch granules take up water and start to swell? and form a gel.
c) The process when bacteria has infected food and causes food poisoning.
d) None
e) I am not sure

Q3.3: *Rope* is caused by spore-forming bacteria (B. *subtilis* and B. *mesentericus*) occurring on wheat and hence in flour. The spores can survive baking and then are present in the bread which then leads to the formation of discoloration, fine silky threads when slices of the crumb are pulled apart, and a characteristic fruity odour (in **Microorganisms** > **Bacteria**) Yes / No

Q3.4: *Chlorination* is the treatment found in which one of the following (in **Bakery Ingredients**)
k) Wheat flour
l) Sugar
m) Dairy products
n) None
o) I am not sure

Q3.5: One of *the functions of milk / dairy products in breads* is to give structure (in **Baking Ingredients** > **Milk and Other Dairy Products**). Yes / No

Q3.6: What is *gluten*? and please name *the two essential compounds* involved in its formation (in **Proteins**).

____

Q3.7: Name the *classification of cookies or biscuits* and what is *the difference between macaroons and ladyfingers.* (in **Bakery Products** > **Cookies**).

____

Q3.8: Cakes *are classified based on* ***ingredients*** *and* ***mixing methods*** into batter-type and foam-type (in **Cakes**). Yes / No

Q3.9: What is *foreign materials control*? What do they do in bakery technologies? (in **Bakery Sanitation**).

____

Time finish __________ (e.g. 10:09 am)

4. *Call the instructor* to proceed to the experiment for the prototype system (**system 3**).

5. In the system 3, please *select the Personalised Links Assistant interface* ***anything you prefer*** and *locate the following terms* and *circle* them if you have found them, and do not forget to write down the start and finish time. Do not worry if you cannot finish them within the required time (***5 minutes***).

Time start _______ (e.g. 09:09 am)

Crumb (in **Basic Food Science** > **Carbohydrates** > **Starches and Their Properties**)
Gluten (in **Basic Food Science** > **Proteins > Gluten as a Protein**)
Caramel (in **Bakery Ingredients** > **Sugars and Syrups** > **Functions of Sugars in Bakery Products**)
Rope (in **Basic Food Sciece** > **Microorganism** > **Bacteria** > **Roles of Bacteria**)

Time finish _______ (e.g. 10:09 am)

6. *Call the instructor* to proceed to the experiment for the prototype system (**system 2**).

7. At the *Table of Contents,* please select **Basic Food Science** > **Proteins > Gluten as a Protein.**

8. Please *consider* and *count* the number of links approxiately. _______

9. Now please *call the instructor* to proceed to the experiment for **system 3**.

10. In system 3, please *select* the *Personalised Links Assistant interface* as ***'all links'***.

11. Please *consider* **the links** and *count* the number of links approxiately. ________

12. *Select* the ***Personalised Links Assistant interface*** and **the *Expertise Dimensions*** as ***'basic'***and ***Language*** as ***'English'.***

13. Please *consider* again **the links** and *count* the number of links approximately. ________

14. *Concentrate* on the link for the word ***'dough'*** and *follow the link* to its explanation.

15. *Reselect* the ***Personalised Links Assistant interface*** > **the *Expertise Dimensions*** as ***'basic'*** and ***Language*** as ***'Spanish'.***

16. *Concentrate* again on the link for the word ***'dough'*** and *follow the link* to its explanation. Describe? what you see. ________________________

17. This time, please *select* the ***Personalised Links Assistant interface*** and **the *Expertise Dimensions*** as ***'advanced*** (the ***Language*** is still chosen as '***Spanish'***).

18. Consider the word ***'dough'*** again and count the number of links approximately. ________

19. What are your opinions? Select the statement that is most appropriate for you.

i) I found *Tables of Contents* (**system 1**) helped me find the document.

Agree	Not sure	Disagree

Any comments?

____

ii) I found the system with *Personalised Links Presentation and Personalisation tools* (**as in system 3**) helped me find the document.

Agree	Not sure	Disagree

Any comments?

____

iii) I found that there were too many links inserted into the document in the '*system with all additional links but no control over links presentation* (**system 2**) and some of these links were what I had already known.

Agree	Not sure	Disagree

Any comments?

____

iv) I found the '*system with all additional links but no control over links presentation'* (**system 2**) useful.

Agree	Not sure	Disagree

Any comments?

____

v) I found the 'system with *links presentation and personalisation'* (**system 3**) were useful as it allowed me to select the links to be displayed ('*all links*', '*basic*', or '*advanced*'), or not to be presented (*'no links'*).

Agree	Not sure	Disagree

Any comments?

____

vi) I found *the system with the Links Presentation and Personalisation tools* (**system 3**) enabled me to have control over the links presentation and personalisation, that is, I could select the links to be presented.

Agree	Not sure	Disagree

Any comments?

____

vii) I think *the MDL concept* and the *Personalised Links Assistant* were useful, as they allowed the same keyword to become different links based on the user's selection (e.g. '*wheat*' could be a link pointing to its definition, or a link pointing to the origin in Latin, depending on the user's selection of links presentation).

Agree	Not sure	Disagree

Any comments?

____

viii) I think *the MDL concept* and the *Personalised Links Assistant* could solve some of the problems of too many additional links being inserted into the document, when these links might not be of concern not only in this specific domain, but also in bigger hyperspace.

Agree	Not sure	Disagree

Any comments?

____

ix) I think *the Links Presentation and Personalisation* interfaces were user-friendly and easy to use.

Agree	Not sure	Disagree

Any comments?

____

x) I would prefer to use the following system to locate the documents and perform all required tasks in the future.

- ○ Table of contents (**system 1**)
- ○ System *with additional links but no control over link presentation* (**system 2**)
- ○ System *with links presentation and personalisation* (**system 3**)

Any comments?

____

xi) I would prefer to use the following system for *links presentation*.

- ○ System *with additional links but no control over link presentation* (**system 2**)
- ○ System *with links presentation and personalisation* (**system 3**)
- ○ None

Any comments?

____

Thank you very much for your time and kind co-operation.
All information given will be kept confidentially

V) Questionnaires for User's Opinion about the System

Please select one of the following scales to reflect upon how you feel about the usefulness of the concept of a Multi-Dimensional Linkbase (MDL) as applied to the Inquiry-led Personalised Navigation System (IPNS).

Affect - user's emotions toward the usage of the system	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
1. I enjoyed interacting with the system.					
2. The system was confusing to use.					
3. The system was not enjoyable to use.					
4. The system is one that I would want to use on a regular basis.					
5. I would recommend this system to my colleagues.					
Control – the degree to which the user feels that they are in control.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
6. The system responded to my inputs.					
7. I did not find it easy to start the system.					
8. I did not have control over the system.					
9. The system did respond slowly to my selections.					
10. The system did exactly what I wanted it to do.					
Efficiency – the degree to which users can complete tasks in a direct and timely fashion.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
11. There were too many steps needed to get to the information.					
12. I was not able to find the task required.					
13. It was straightforward to get to the information for the specified task.					
14. The system allows users to adjust the setting to suit their needs.					
15. The system allows the task to be completed more quickly.					
Helpfulness – the extent to which the system assists the user in a situation.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
16. The system was helpful in finding what I needed.					
17. There was insufficient information on how to proceed with the system and the tools.					
18. The inquiry tools provided enough assistance.					
19. I could not understand how to use the tools and did not find these tools useful.					
20. I found the tools awkward to use/interact with.					

Learnability – the degree to which the system is easy for users to learn how to use.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
21. Learning to use the system was straightforward.					
22. The given guidance before using the system was enough to allow users to use the system.					
23. I found the system easy to learn and use.					
24. Learning to use different tools were difficult.					
25. The system is easy to become familiar with.					
Navigation – the ability that users can move around the system.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
26. It was uncomplicated to move around the information space.					
27. The system tools provided assist in navigation.					
28. It was easy to become disoriented when interacting with the system tools.					
29. I knew how to find my way around the system using the personalised features provided.					
30. I did not find the system tools useful.					
Comprehension – the degree to which users can understand the interaction with the system.	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
31. I did not understand the interaction with the system.					
32. The information was presented clearly and consistently.					
33. The system tools were satisfactorily presented.					
34. The tools were easy to understand.					
35. I did not understand the action provided by the tools.					
Other Comments	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
36. Overall reactions to using the system and the provided tools.					
o Difficult					
o Easy					
o Disappointing					
o Satisfactory					
37. Additional comments on the system.					
38. Additional comments on the provided tools.					
39. Additional comments in general.					

Appendix C. Data from Experimental Study

I) Heuristic Evaluation

Expert	Flexibility and Efficiency of Use	Easy to comprehend	Easy to remember	Pleasant to Use	User Control and Freedom	Few Errors	Consistency	Aesthetic and Minimalist Design	Match between the System and the Real World
expert1	5	4	4	5	5	4	5	4	5
expert2	4	4	4	4	4	4	4	4	4
expert3	4	3	5	3	5	5	5	4	4
expert4	4	4	4	3	4	2	2	4	2
expert5	4	4	5	3	3	4	4	4	3
expert6	5	3	4	4	4	5	2	3	3
expert7	4	4	4	3	4	3	3	4	4
expert8	4	5	3	4	5	3	4	4	4
expert9	4	5	4	4	4	3	4	4	4
Total	38	36	37	33	38	33	33	35	33
Average	4.22	4.00	4.11	3.67	4.22	3.67	3.67	3.89	3.67

Comments:

The following comments were made by some of the expert evaluators and are quoted here verbatim.

Flexibility and Efficiency of Use

- The prototype was common for web users. They could therefore use the system to perform their task without difficulty.
- The system provides more functionality than the other general websites I have visited. The linkbase such as 'Language' is useful for users in different parts of the world to understand more about contents within web pages

- The tools are friendly for all users. They react immediately with input. However, it needs further clarification on how to use and examples should be provided.
- For the *Personalised Link Assistant* tool, sometimes the resulting links do not reflect the language changes. However, it might be a coding mistake. All in all, I like this idea of personalised links

Easy to Comprehend

- It would be beneficial if users can see which dimension the word comes from.
- *Personalised Links Assistant* is a very good idea and easy to use. Inquiry Assistant is a good idea but the presentation of results is less clear than it could have been. Definitions of relationship types are unclear.
- Appearance and disappearance of links definitely satisfy users.
- I understand most interactions with the system. However, I do not understand the given links from the *Inquiry Links* tool (It doesn't relate to what I made inquiry).
- The system employed standard interfaces such as buttons, pull down menu, etc.; simple words for links, such as 'no links', 'all links', 'basic links', and 'advanced links' are easy to understand. Using colour to tell the user about different kind of relationship types makes sense for users.

Easy to Remember

- Apart from the definition of relationship types for the *Inquiry interface*.
- Users need to learn how to use the system before using it but it is not hard to remember the instruction.
- It was implemented to be very easy to use. I do not need to restudy the instructions. It is intuitive.
- I find the *Inquiry Assistant* tool is hard to understand. The information presented is not clear enough. Personalised Links Assistant tool is very clear to understand.
- The design of the system is not too complex. The Assistant tools were designed and placed on top of the top navigation menu. Users can remember these tools and where to find them. The 'Select Text' button at the bottom of each page can warn users that there is a help function to assist users in finding more explanation when they want one.

Pleasant to Use

- The UI should be adjusted to provide more convenience to users.
- I would hope to have a 'Back' button to point me back to the search result tree from the *Inquiry Links* tool (or any previous page about what I made a mistake).
- There are some good and bad UI parts. Some good UI: the system provides the description of terms such as 'relationship types', in addition to what the Tools can provide. Some bad UI: The design of the 'Select Text' button in each page can be more flexible with the design of the left mouse click etc.

User Control and Freedom

- It is good that that system allows users to select which dimensions of links to show.
- It saves time for users to be able to get rid of irrelevant contents (links).
- With the *Personalised Links Assistant* tool I feel in control (except when system crashes).
- The system is preferable to users because the system provides function such as *Personalised Links Assistant* function to present users with something users can decide to see at a time. 'No link' option can make the experienced users or expert users with a non link insertion version. 'All links' selection can make inexperienced users to see all presenting links.

Few Errors

- Sometimes when there supposed to be some links displayed, the links do not display while browsing the documents.
- I have not found many errors, apart from the Inquiry links (it might be due to the limitation of my understanding).
- The word 'rope' is presented as a link in the word 'properties'.
- I have not found many errors, apart from the Inquiry links (it might be due to the limitation of my understanding).
- Links all seem to be relevant.
- I found just a few errors from the system.

Consistency

- There are some technical terms that may be unknown to some inexperienced users.
- I found the system is consistent.
- Follow Links failed to find link on keyword 'dough' but I know one exist.
- All pages used same language, format, position, etc.

Aesthetic and Minimalist Design

- The *Personalised Links Assistant* is good. The results from Inquiry Assistant in textual form are a bit difficult to use and see. It would be easier to see and read if the results are displayed in the visual graph.
- Yes, it was good design - but I would place the button for the *Follow Links* function with the other Adaptive Assistant Tools at the top of the navigation menu.
- I like the design of the system, it is easy to handle and follow. The reaction time is short.
- Linking in body is good but still I find many keyword links repeating themselves e.g. 'dough'.
- The system used colour annotation to show the relationship and paths of the concept in the concept relationship (domain ontology) in Inquiry Links Assistant tool; therefore, users can understand easily about the difference. However, the system can be more interesting when using "Java Interactive" "Audio or Video" to create the interactive system.

Match between the System and the Real World

- It would be better to replace some technical wording in relationship types with simpler meanings.
- I assume it might be difficult for some users to understand the Inquiry Links and the Follow Links tool would help in their study of the subject. Maybe more background information is needed.
- The Inquiry assistant failed, otherwise it appears fine.

Other comments

- Some more clarifications about how to use tools are necessary.

- It would be nice to know which dimension the links come from e.g. different colour per dimension.
- I found it quite difficult to understand the system at first, but after that, I got used to it and it worked ok.
- The design of the assistant tools can be improved to make it more usable. However, it should be careful about too much assistance as it could take time for users to configure the setting that they want. It may cause users denial to use the system.

II) Empirical Evaluation: Experiment 1

User	System 1							System 3						
	Time (min.)	(%) 1	No. of Questions Completed	(%) 2	Score	(%) 3	Percentage Of Tasks Completed (1+2+3)	Time (min.)	(%) 1	No. of Questions Completed	(%) 2	Score	(%) 3	Percentage of Tasks Completed (1+2+3)
Gr2.1(1)	11	**100**	5	**55.56**	3	**33.33**	**188.89**	10	**100**	7	**77.78**	4.5	**50**	**227.78**
Gr2.1(2)	16	**90**	4	**44.44**	3	**33.33**	**167.78**	11	**100**	5	**55.56**	3	**33.33**	**188.89**
Gr2.1(3)	10	**100**	5	**55.56**	5	**55.56**	**211.11**	10	**100**	6	**66.67**	4.5	**50**	**216.67**
Gr2.1(4)	21	**80**	9	**100**	6	**66.67**	**246.67**	11	**100**	9	**100.00**	7.5	**83.33**	**283.33**
Gr2.1(5)	14	**100**	9	**100**	5	**55.56**	**255.56**	8	**100**	9	**100.00**	6	**66.67**	**266.67**
Gr2.1(6)	35	**70**	7	**77.78**	5	**55.56**	**203.33**	15	**100**	8	**88.89**	6.5	**72.22**	**261.11**
Gr2.1(7)	22	**80**	7	**77.78**	6	**66.67**	**224.44**	14	**100**	8	**88.89**	7.5	**83.33**	**272.22**
Gr2.1(8)	18	**90**	7	**77.78**	3.5	**38.89**	**206.67**	13	**100**	8	**88.89**	3	**33.33**	**222.22**
Gr2.2(1)	11	**100**	4	**44.44**	2.5	**27.78**	**172.22**	10	**100**	7	**77.78**	5.5	**61.11**	**238.89**
Gr2.2(2)	15	**100**	6	**66.67**	5.5	**61.11**	**227.78**	11	**100**	9	**100**	7	**77.78**	**277.78**
Gr2.2(3)	10	**100**	9	**100**	4	**44.44**	**244.44**	19	**90**	9	**100**	4	**44.44**	**234.44**
Gr2.2(4)	17	**90**	9	**100**	6	**66.67**	**256.67**	26	**80**	9	**100**	6.5	**72.22**	**252.22**
Gr2.2(5)	13	**100**	7	**77.78**	5.5	**61.11**	**238.89**	20	**90**	9	**100**	7	**77.78**	**267.78**
Gr2.2(6)	10	**100**	5	**55.56**	5	**55.56**	**211.11**	15	**100**	6	**66.67**	5	**55.56**	**222.22**
Gr2.2(7)	10	**100**	7	**77.78**	4.5	**50.00**	**227.78**	20	**90**	6	**66.67**	3.5	**38.89**	**195.56**
Gr2.2(8)	17	**90**	9	**100**	8	**88.89**	**278.89**	12	**100**	9	**100**		**88.89**	**288.89**

III) Empirical Evaluation: Experiment 2(a)

Group 1	**System 2**					**Group 2**	**System 3**				
	Time (min)	(%) -1-	No. of Terms Found (Total = 4)	(%) -2-	Speed of Navigation -(1+2)-		Time (min)	(%) -1-	No. of Terms Found (Total = 4)	(%) -2-	Speed of Navigation -(1+2)-
Gr1(5)	3	**80**	4	**100**	**180**	Gr2(1)	2	**90**	4	**100**	**190**
Gr1(6)	5	**60**	2	**80**	**140**	Gr2(5)	3	**80**	4	**100**	**180**
Gr1(7)	2	**90**	3	**90**	**180**	Gr2(6)	2	**90**	4	**100**	**190**
Gr1(8)	2	**90**	4	**100**	**190**	Gr2(7)	4	**70**	3	**90**	**160**
Gr1(9)	2	**90**	4	**100**	**190**	Gr2(8)	1	**100**	4	**100**	**200**
Gr1(10)	3	**80**	4	**100**	**180**	Gr2(9)	2	**90**	4	**100**	**190**
Gr1(11)	1	**100**	4	**100**	**200**	Gr2(11)	2	**90**	4	**100**	**190**
Gr1(12)	6	**50**	3	**90**	**140**	Gr2(12)	5	**60**	4	**100**	**160**

IV) Empirical Evaluation: Experiment 2(b)

Subjective feedback	Agree	Neutral	Disagree
Q1. I found System Non (i.e. using table of contents) helped me find the document.	10	5	1
Q.2 I found the IPNS prototype helped me find the document.	14	2	0
Q3. I found that there were too many links in System All links and some of these links were what I had already known.	11	5	0
Q4. I found System All links presentation useful.	8	8	0
Q5. I found the IPNS prototype were useful as it allowed me to select the links to be displayed (*'all links'*, *'basic links'*, *'advanced links'*) or not to be presented (*'no link'*).	15	1	0
Q6. I found the IPNS enabled me to have control over the link presentation and personalisation, that is, I can select the links to be presented.	12	3	1
Q7. I think *the MDL concept* and the *Personalised Links assistant* interface was useful as it allowed a same keyword to become different links based on the user's selection.	13	3	0
Q8. I think the *MDL concept* and the *Personalised Links assistant* interface could solve some of the problems of too many additional links inserting into the document, whereby these links might not be of concerns, not only in this specific domain, but also in bigger hyperspace.	13	3	0
Q9. I think the links presentation and personalisation interfaces were user-friendly and easy to use.	10	6	0
Q10. I would prefer to use the following systems to locate the documents and perform all required tasks in the future • System Non link • System All links • IPNS	 4 2 10		
Q11. I would prefer to user the following system for links presentation • System All links • IPNS • None	 2 14 0		

V) Empirical Evaluation: Experiment 3 (Raw Data)

Users / **Criteria**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Affect																								
1. I enjoyed interacting with the system.	4	4	3	3	3	4	4	5	3	3	5	4	4	4	4	3	3	4	4	4	5	3	4	4
2.The system was confusing to use.	2	2	3	3	4	2	2	2	3	2	2	3	3	3	2	3	2	2	2	3	2	3	3	2
3. The system was not enjoyable to use.	2	2	3	3	3	2	3	2	2	2	2	2	2	2	2	3	2	2	3	2	2	2	2	2
4. The system is one that I would want to use on a regular basis.	4	4	4	4	2	4	5	5	4	4	5	4	3	3	4	4	4	4	4	4	3	4	3	4
5. I would recommend this system to my colleagues.	4	4	3	3	3	4	5	5	3	3	5	3	3	4	4	4	3	4	3	4	5	4	4	4
Control																								
6. The system responded to my inputs.	4	4	4	3	3	4	4	4	4	5	4	3	4	4	5	4	5	4	4	4	3	4	5	4
7. I did not find it easy to start the system.	3	2	3	3	1	4	2	2	2	3	2	3	4	2	2	2	3	2	3	4	2	3	4	2
8. I did not have control over the system.	2	2	3	3	2	2	2	2	3	2	2	3	2	4	3	2	2	2	2	2	2	2	1	2
9. The system did respond slowly to my selections.	2	2	3	3	4	3	2	2	4	2	3	3	2	2	2	2	2	3	3	3	2	3	3	2
10. The system did exactly what I wanted it to do.	4	4	3	3	4	3	4	5	3	5	4	4	3	4	4	4	5	4	4	3	2	3	4	4
Efficiency																								
11. There were too many steps needed to get to the information.	2	2	3	3	4	2	3	3	2	3	2	4	2	3	3	3	3	2	2	2	3	2	3	2
12. I was not able to find the task required.	2	2	3	4	3	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
13. It was straightforward to get to the information for the specified task.	3	4	3	2	4	3	4	5	3	3	5	4	4	4	3	4	3	3	3	2	4	3	4	3
15. The system allows the task to be completed more quickly.	4	5	4	3	3	3	4	4	3	4	5	5	4	4	4	4	4	4	5	5	4	4	3	4
Helpfulness																								
16. The system was helpful in finding what I needed.	4	4	4	3	3	2	4	5	3	4	5	4	4	4	5	4	4	4	5	4	4	4	4	4
17. There was insufficient information on how to proceed with the system and the tools.	3	2	4	3	4	2	2	2	3	3	2	3	3	4	2	3	3	2	3	2	3	3	3	2
18. The inquiry tools provided enough assistance.	4	3	4	2	3	3	3	4	4	3	4	3	3	5	3	4	3	3	4	3	3	3	4	3
19. I could not understand how to use the tools and did not find these tools useful.	2	2	2	3	3	3	2	2	2	1	2	2	2	5	2	2	1	2	2	2	2	2	2	2
20. I found the tools awkward to use/interact with.	2	2	2	3	4	2	3	2	4	1	2	3	2	5	2	2	1	2	1	2	2	2	2	2

Learnability																								
21. Learning to use the system was straightforward.	4	4	4	3	4	4	5	5	4	4	5	4	2	4	4	4	3	4	3	4	5	3	4	4
22. The given guidance before using the system was enough to allow users to use the system.	4	4	4	5	4	4	5	4	3	4	5	4	2	4	4	4	2	4	4	4	4	2	4	4
23. I found the system easy to learn and use.	4	4	4	3	3	4	4	4	4	4	5	4	2	3	4	4	4	4	4	4	4	3	4	4
24. Learning to use different tools were difficult.	2	2	3	3	2	2	2	2	3	3	3	2	4	4	2	2	2	2	2	2	2	3	2	2
25. The system is easy to become familiar with.	4	4	4	3	3	4	4	4	3	4	5	4	4	2	4	4	4	3	4	4	4	3	5	4
Navigation																								
26. It was uncomplicated to move around the information space.	4	4	3	3	2	4	4	2	4	2	5	3	4	4	3	4	4	4	4	4	4	4	4	4
27. The system tools provided assist in navigation.	5	3	4	3	3	3	4	4	4	4	5	4	4	4	3	4	4	4	3	4	4	4	3	4
28. It was easy to become disoriented when interacting with the system tools.	3	3	3	3	3	2	4	3	3	2	2	3	3	3	2	3	2	2	2	2	3	2	4	3
29. I knew how to find my way around the system using the personalised features provided.	5	3	4	4	4	4	4	4	4	4	5	4	3	4	4	4	4	4	3	4	4	4	5	4
30. I did not find the system tools useful.	2	2	3	3	3	3	2	1	3	1	2	2	2	2	2	2	1	2	2	2	2	2	2	2
Comprehension																								
31. I did not understand the interaction with the system.	2	2	3	2	2	2	3	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	1	2
32. The information was presented clearly and consistently.	3	3	4	3	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	3	4	3	4	4
33. The system tools were satisfactorily presented.	4	4	4	3	4	4	4	5	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4
34. The tools were easy to understand.	4	4	4	2	3	4	4	4	3	4	5	4	3	4	4	4	4	3	4	4	4	3	5	4
35. I did not understand the action provided by the tools.	2	2	2	2	3	3	2	2	2	2	2	3	3	2	3	2	2	2	2	2	2	2	1	2
Overall reactions to using the system and the tools provided																								
Difficult	3	2		3	2	2	2	2	3	2	1	2	3	2	2	2	2	2	2	2	2	2	2	2
Easy	4	4		3	4	4	4	4		4	5	4	3	4	4	4	4	4	4	4	4	3	4	4
Disappointing	2	2		4	3	3	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
Satisfactory	4	4	4	3	3	4	4	4		4	5	4	4	5	4	4	4	5	4	4	4	4	4	4

VI) Empirical Evaluation: Experiment 3 (Prepared Data for Statistical Analysis:- after subtracting 15 from the Sum)

User	Affect		Control		Efficiency		Helpfulness		Learnability		Navigation		Comprehension		Overall reactions							
															Diff		Easy		Disap		Satis	
1	4 4 4 4 4 20	5	4 3 4 4 4 19	4	4 4 3 4 4 19	4	4 3 4 4 4 19	4	4 4 4 4 4 20	5	4 5 3 5 4 21	6	4 3 4 4 4 19	4	3	0	4	1	2	-1	4	1
2	4 4 4 4 4 20	5	4 4 4 4 4 20	5	4 4 4 5 5 22	7	4 4 3 4 4 19	4	4 4 4 4 4 20	5	4 3 3 3 4 17	2	4 3 4 4 4 19	4	2	-1	4	1	2	-1	4	1
3	3 3 3 4 3 16	1	4 3 3 3 3 16	1	3 3 3 3 4 16	1	4 2 4 4 4 18	3	4 4 4 3 4 19	4	3 4 3 4 3 17	2	3 4 4 4 4 19	4							4	1
4	3 3 3 4 3 16	1	3 3 3 3 3 15	0	3 2 2 3 3 13	-2	3 3 2 3 3 14	-1	3 5 3 3 3 17	2	3 3 3 4 3 16	1	4 3 3 2 4 16	1	3	0	3	0	4	1	3	0
5	3 2 3 2 3 13	-2	3 5 4 2 4 18	3	2 3 4 3 3 15	0	3 2 3 3 2 13	-2	4 4 3 4 3 18	3	2 3 3 4 3 15	0	4 4 4 3 3 18	3	2	-1	4	1	3	0	3	0
6	4 4 4 4 4 20	5	4 2 4 3 3 16	1	4 3 3 4 3 17	2	2 4 3 3 4 16	1	4 4 4 4 4 20	5	4 3 4 4 3 18	3	4 4 4 4 3 19	4	2	-1	4	1	3	0	4	1
7	4 4 3 5 5 21	6	4 4 4 4 4 20	5	3 4 4 5 4 20	5	4 4 3 4 3 18	3	5 5 4 4 4 22	7	4 4 2 4 4 18	3	3 4 4 4 4 19	4	2	-1	4	1	2	-1	4	1
8	5 4 4 5 5 23	8	4 4 4 4 5 21	6	3 4 5 4 4 20	5	5 4 4 4 4 21	6	5 4 4 4 4 21	6	2 4 3 4 5 18	3	4 4 5 4 4 21	6	2	-1	4	1	2	-1	4	1
9	3 3 4 4 3 17	2	4 4 3 2 3 16	1	4 3 3 4 3 17	2	3 3 4 4 2 16	1	4 3 4 3 3 17	2	4 4 3 4 3 18	3	4 3 4 3 4 18	3	3	0			2	-1		
10	3 4 4 4 3 18	3	5 3 4 4 5 21	6	3 4 3 5 4 19	4	4 3 3 5 5 20	5	4 4 4 3 4 19	4	2 4 4 4 5 19	4	4 4 4 4 4 20	5	2	-1	4	1	2	-1	4	1
11	5 4 4 5 5 23	8	4 4 4 3 4 19	4	4 4 5 5 5 23	8	5 4 4 4 4 21	6	5 5 5 3 5 23	8	5 5 4 5 4 23	8	4 4 4 5 4 21	6	1	-2	5	2	2	-1	5	2
12	4 3 4 4 3 18	3	3 3 3 3 4 16	1	2 4 4 5 5 20	5	4 3 3 4 3 17	2	4 4 4 4 4 20	5	3 4 3 4 4 18	3	3 4 4 4 3 18	3	2	-1	4	1	2	-1	4	1
13	4 3 4 3 3 17	2	4 2 4 4 3 17	2	4 4 4 4 4 20	5	4 3 3 4 4 18	3	2 2 2 2 4 12	-3	4 4 3 3 4 18	3	3 4 4 4 4 19	4	3	0	3	0	2	-1	4	1
14	4 3 4 3 4 18	3	4 4 2 4 4 18	3	3 4 4 5 4 20	5	4 2 5 1 1 13	-2	4 4 3 2 2 15	0	4 4 3 4 4 19	4	4 4 4 4 4 20	5	2	-1	4	1	1	-2	5	2
15	4 4 4 4 4 20	5	5 4 3 4 4 20	5	3 4 3 4 4 18	3	5 4 3 4 4 20	5	4 4 4 4 4 20	5	3 3 4 4 4 18	3	4 4 4 4 3 19	4	2	-1	4	1	2	-1	4	1
16	3 3 3 4 4 17	2	4 4 4 4 4 20	5	3 4 4 4 4 19	4	4 3 4 4 4 19	4	4 4 4 4 4 20	5	4 4 3 4 4 19	4	4 4 4 4 4 20	5	2	-1	4	1	2	-1	4	1
17	3 4 4 4 3 18	3	5 3 4 4 5 21	6	3 4 3 5 4 19	4	4 3 3 5 5 20	5	3 2 4 4 4 17	2	4 4 4 4 5 21	6	4 4 4 4 4 20	5	2	-1	4	1	2	-1	4	1
18	4 4 4 4 4 20	5	4 4 4 3 4 19	4	4 4 3 5 4 20	5	4 4 3 4 4 19	4	4 4 4 4 3 19	4	4 4 4 4 4 20	5	4 4 4 3 4 19	4	2	-1	4	1	2	-1	5	2
19	4 4 3 4 3 18	3	4 3 4 3 4 18	3	4 4 3 4 5 20	5	5 3 4 4 5 21	6	3 4 4 4 4 19	4	4 3 4 3 4 18	3	4 4 3 4 4 19	4	2	-1	4	1	2	-1	4	1
20	4 3 4 4 4 19	4	4 2 4 3 3 16	1	4 4 2 4 5 19	4	4 4 3 4 4 19	4	4 4 4 4 4 20	5	4 4 4 4 4 20	5	4 3 4 4 4 19	4	2	-1	4	1	2	-1	4	1
21	5 4 4 3 5 21	6	3 4 4 4 2 17	2	3 4 4 5 4 20	5	4 3 3 4 4 18	3	5 4 4 4 4 21	6	4 4 3 4 4 19	4	4 4 4 4 4 20	5	2	-1	4	1	2	-1	4	1
22	3 3 4 4 4 18	3	4 3 4 3 3 17	2	4 3 3 4 4 18	3	4 3 3 4 4 18	3	3 2 3 3 3 14	-1	4 4 4 4 4 20	5	4 3 4 3 4 18	3	2	-1	3	0	2	-1	4	1
23	4 3 4 3 4 18	3	5 2 5 3 4 19	4	3 3 4 5 3 18	3	4 3 4 4 4 19	4	4 4 4 4 5 21	6	4 3 2 5 4 18	3	5 4 4 5 5 23	8	2	-1	4	1	2	-1	4	1
24	4 4 4 4 4 20	5	4 4 4 4 4 20	5	4 3 3 4 4 18	3	4 4 3 4 4 19	4	4 4 4 4 4 20	5	4 4 3 4 4 19	4	4 4 4 4 4 20	5	2	-1	4	1	2	-1	4	1

Appendix D. HCI Evaluation Methods and Techniques

There are a number of disciplines in classification of methods and techniques for HCI evaluation. However, this thesis follows closely the guideline presented by Wills (2005a) which reviewed the five evaluation methods, namely, *observation*, *users' opinion*, *experiments, interpretive,* and *predictive*. Each comprises its own techniques and some techniques are methods in their own right. This section gives a concise overview of the evaluation methods and their techniques.

Observation **–** a method to observe or monitor how users interact with a system which can be undertaken informally and/or formally. Problems the user has with the system interaction can also be identified and understood. The techniques include *direct observation* (i.e. observing users carrying out their routine work or specially designated tasks and making notes based upon the observation), *audio or video recording* (i.e. using cameras or videos to record the users' interaction and their body language, directly or indirectly), *software logging* (i.e. collecting the user actions as they interact with the system by using a piece of software logging), and *protocol analysis* (i.e. a technique which users are asked to interact with the system and to supply their thoughts, feeling, opinions and actions verbally – 'think aloud' (Jorgensen, 1990)).

Users' opinion – a method to gather users'attitudes about a system. The two main techniques are *interviews* and *questionnaires*. Interview is an essential technique to capture in-depth information such as attitudes, impressions, opinions and ideas (Dix *et al*., 2003). Structured interview is a pre-planned form of the interview with a defined sequence of questions and allowing no exploration of individual attitudes, whereas flexible (or unstructured) interview defines some set of topics but not exact sequence (Preece *et al.*, 1993). Questionnaire provides another means of capturing users' opinions. Although it is less flexible than the interview because questions are fixed, it is particularly useful for large data collection. The questions can be designed for qualitative and quantitative data analysis depending on what is being assessed.

Designing questionnaries is essential as it can be time-consuming. Closed questions provide the respondent with a choice of possible answers, while open questions allow the respondent to provide their own answers freely. The fact that users can give their responses anonymously is also one of the advantages of gathering user's preference with questionnaires.

Experiments **–** a means to allow evaluators to manipulate experimental variables involved in the system, normally a full prototype, and observe their effects on aspects of performance of the users (Wills, 2005a). Users are also required in this kind of evaluation. The purpose of the evaluation, the experimental variables, and the hypotheses need to be clearly specified. The selection of the statistical tests is also crucial to assess the reliability of the results (Preece *et al*., 1993). Usability engineering is a technique in this category applied to measure whether users can operate the system to the approved level of predefined usability.

Interpretive **–** an approach where data on how people use technology in real work environments is collected and analysed. Techniques such as *contextual inquiry* (a structured field interviewing method to understand how users operate the system in their actual work context (Hom, 1998), *co-operative evaluation* (a method in which users work with a prototype carrying out sets of designated tasks with evaluator's observation and while doing it users give details what they are doing – 'think aloud' (Monk *et al*., 1993), and *participative evaluation* (a technique that users and evaluators collaborate on interpreting protocols (Wright and Monk, 1989), are examples of this evaluation method.

Predictive **–** a method that attempts to reduce the cost of usability evaluation by predicting of user interaction. It involves experts who are specialist in the technology and with no or only limited end user engagement. It is said to be comparatively quicker and cheaper to undertake (Wills, 2000). Example techniques comprise *usage simulation* (a technique where experts simulate the behaviour of less experienced users and review the system to find out any usability problems, so-called 'expert reviews'), *structured expert reviewing* (a technique that is similar to the usage simulation but with more structured, prescriptive and focused tasks), *heuristic evaluation* (a technique developed by Nielsen and Morlich (1990) to assess a system using a set of general guidelines or principles – "heuristics" undertaken by a number of evaluators independently engaging in reviewing and discussing the system and coming up with usability problems (Dix *et* *al*., 2003), and *walkthroughs* (a technique originated from the code walkthrough technique in software engineering that aims to detect and removed problems early on by involving a defined group of experts in reviewing a prepared, detailed review of a sequence of actions that result in accomplished tasks.)

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