Design Guidelines and User-Centred Digital Libraries

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Abstract. As current digital libraries are becoming more complex, the facilities provided by them will increase and the difficulty of learning associated with the complexity of using these facilities will also increase. In order to produce usable and useful interactive systems, designers need to ensure that good design features are incorporated into the systems, taking into consideration end-users' needs and cultural backgrounds. We carried out a study to investigate useful design features digital libraries should have. The study provides insights on the usability impact of digital libraries for task completion and end-users' perceived impressions on the effectiveness of the digital libraries. The results also suggest that there is little provision on the interface to cater to end-users' browsing and inter-cultural needs. Hence, this paper also discusses design guidelines for the design of user-centred digital libraries.

1 Introduction

The growing popularity of the Internet and advancements in networking has brought about networked hypertext systems such as the Web. In recent years, the Web, the overwhelming example of a shared world-wide collection of information, has been extended to include many digital libraries by individuals or groups that select, organise, and catalogue large numbers of documents.

Although there is as yet no consensus on the definition of *digital libraries*, they are generally referred to as "collections of information that are both digitised and organised" [13], and give us opportunities we never had with traditional libraries or even with the Web. Digital libraries are emerging and the digital computer is the technology that has enabled Bush's "memex" to be finally realised [3]. For universities and libraries to retain their status and relevance, they have to participate in the new digital world, as indeed many already do such as the British Library, The Library of Congress in the United States, *etc.*

Although a significant resource of digital libraries has been established with a large number of potential users, a pressing research challenge still remains in developing appropriate facilities to promote world-access and use of the growing of digital information. Several studies have shown that users have great difficulty using

relatively basic Online Public Access Catalogues (OPACs). These difficulties are in part caused by the conflation of a number of problems:

- difficulty of learning to use any new piece of software;
- difficulty for a non-expert to learn the organisation of information in a library;
- difficulty of learning the particular details of organisation in an unfamiliar library; and
- difficulty of using Boolean search operators for many users.

As the facilities provided by on-line resources increase, it is likely that the difficulty of learning associated with complexity in using these facilities will persist and may continue to increase.

2 Problems with Digital Libraries

Current digital libraries are becoming more complex systems which include text search, functionality relating to hypertext, multimedia, the Web and highly interactive interfaces [20]. If we have problems producing good web sites as evidenced by much research done to address problems on the Web [26], then it would not be unreasonable to anticipate that we will have problems creating good digital libraries! This is because digital libraries are *more than* just web sites or stores of information in digital libraries. Designers need to provide efficient ways to structure information, and represent them digitally using computers. To design good, usable digital libraries, one requires knowledge about who will use them, what they will be used for, the work context and the environment in which they will be used, and what is technically and logistically feasible. This is all in addition to the usual usability concerns, such as the tasks and populations of users.

This complexity is further compounded by the fact that designers, content providers, and users can have very different cultural backgrounds. Although information in digital libraries is supposed to be available globally, its design, content provision, and use have remained local. This cultural diversity raises a number of questions regarding the cross-cultural usability of digital libraries.

Designing good, usable interfaces is not an easy task. Dix *et al.* argue that even if one has used the best methodology and model in the design of a usable interactive system, one still needs to assess the design and test the system to ensure that it behaves as expected and meets end-users' requirements [8]. Landauer points out that it is impossible to design an optimal user interface in the first try. If information access systems are to provide good, usable interfaces, designers must conduct some form of testing on the interface [11]. However, without knowing where in a system users run into problems, one has little hope of improving the system [18].

3 Our Study

This paper presents a study we carried out as part of a project funded by the UK's Science Research Council (EPSRC). The objectives of our work are to:

- investigate useful design features digital libraries should have by examining three sample digital libraries;
- study the effects of the lack of these design features on end-users' performance in terms of task completion; and
- propose basic design features for the design of digital libraries that will take into account end-users' needs.

The pilot work we have done suggests lots of exciting avenues to research in greater depth.

3.1 Protocol

Ten computing staff and students were selected to evaluate three sample digital libraries: the Networked Computer Science Technical Reference Library (NCSTRL), the New Zealand Digital Library (NZDL) and the ACM Digital Library (ACMDL). These three digital libraries were chosen because they are available to the general public, and are one of the better examples of digital libraries found on the Web in terms of its information and coverage.

NCSTRL is an international collection of computer science research reports and papers made available for non-commercial use from more than 100 participating institutions and archives (see http://www.ncstrl.org/). ACMDL consists of a vast resource of bibliographic information, citation and full-text articles (see http://www.acm.org/). NZDL comprises several demonstration collections such as computer science technical reports, literary works, internet FAQs, and the Computists Communique magazine (see http://www.nzdl.org/).

Seven of the subjects were researchers with some experience in using digital libraries. The other three subjects were non-researchers with no experience with digital libraries but used the web often. Since we are interested in investigating end-users' performance when using digital libraries, we provided the subjects with two tasks that involved search and browsing. We define *browsing* to refer to "navigating without any specific goal or purpose. *Searching* refers to "examining or looking carefully in order to find information". The subjects could choose how long to spend on each task. Table 1 shows the two tasks.

Table 1. Information retrieval tasks given to subjects

Task	**Description of task**
Search	Find a journal article given author's name, title of article, title of journal and year of publication.
Browse	Find all articles by an author between 1996 and 1999, given author's name.

After they had completed the tasks using all three of the digital libraries, they were asked to complete an extensive questionnaire (see section following on the description of the questionnaire) commenting on how satisfied they were with the design and

structure of the digital libraries in helping them to complete the tasks successfully. If not, they would explain the reasons for not being able to complete the tasks successfully. *Satisfaction* refers to the "feeling of being pleased with the digital library in helping to complete the task successfully". *Being pleased* is defined in terms of the subjects' perceived ease of use, rate of errors, and time taken to perform the task successfully.

3.2 Questionnaire

The formulation of the questionnaire was greatly inspired by the development of a measurement tool called the Questionnaire for User Interface Satisfaction (QUIS) by Chin, Diehl and Norman [5]. QUIS measures end-users' subjective ratings of the interface of an interactive system. According to Chin, Diehl and Norman, even though several questionnaires have been developed to assess end-users' perceptions of interactive systems, their weaknesses range from a lack of validation [4] to low reliability [12]. Chin, Diehl and Norman claimed QUIS is reliable. The design of the questionnaire was modelled closely after QUIS, adapted for digital library, because of its reliability as claimed by these authors.

To select the relevant areas to measure usability, we turned to Lingaard's classification of typical usability defects for interactive systems which include [14]: navigation; screen design and layout; terminology; feedback; consistency; modality; redundancies; end-user control and match with end-user tasks. Inspired by Lingaard's classification of usability defects in interactive systems, we then formulated the general design categories for evaluating digital library into nine areas G1 to G9.

G1. Overall reactions to digital library
This area evaluates end-users' overall perception of the performance of hypertext in terms of satisfaction, completion of tasks and appeal.

G2. Screen display
This area measures how clearly information is organised and displayed on the screen.

G3. Terminology and system information
This area examines whether digital library is consistent in the use of terminology, word and format. It also asks if the system provides feedback, and whether error messages are useful.

G4. Learning
This area investigates the ease of use of the digital library.

G5. System capabilities and user control
This area examines digital library's response time, reliability and recovery process.

G6. Digital library site customisation
This area examines whether the designers have taken into consideration end-users' experience and inter-cultural needs.

G7. Navigation
This area asks questions on how clearly are the navigational elements such as maps, table of contents, etc. displayed. It also investigates whether the end-user is "lost", and the reasons why.

G8. Information retrieval
This area asks questions on how the quality of search facilities, quality of search results, and ease of retrieval/downloading of information.

G9. Completing tasks
This area examines the extent of usefulness of facilities in digital library in helping end-users to complete their tasks in browsing and searching.

For the purpose of our study, 36 out of 40 questions were closed questions, since they are generally easier to analyse than open questions [19]. Responses obtained from closed questions can be easily converted into numerical values and a statistical analysis can be performed. Four open questions were asked since they encourage "freer" answers from respondents, hence provide a rich source of data, which may otherwise go undetected.

Generally, end-users prefer concrete adjectives for evaluations [7], therefore the questionnaire used a semantic differential scale, a popular form of attitude scale widely used in HCI research, to measure end-users' responses [19]. This scale has bi-polar adjectives at the end-points, and respondents rate the user interface on a scale between these paired adjectives by putting a tick in the appropriate column .

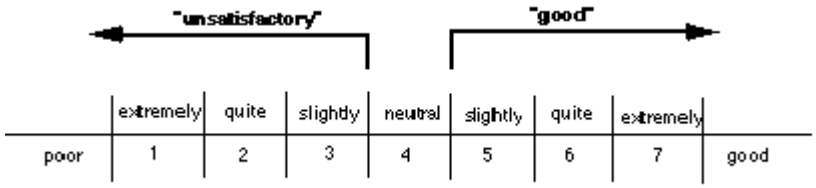

Fig. 1. A 7-point scale to measure end-users' responses

For easier analysis and display of results, the semantic differential scale used in the questionnaire was translated into a 7-point scale (see figure 1). For example, number 1 represents "extremely poor" and number 7 represents "extremely good". A value "5 and above" is considered "good", implying that end-users are generally pleased with the digital library and designers need not make any changes. A value "3 and below" is deemed "unsatisfactory" indicating end-users' dissatisfaction with the digital library, and designers should make necessary changes to correct the deficiency. A mid-value of 4 is taken to be "neutral", and probably designers should find out more from end-users and make changes if required.

4 Results and Analysis

We report our results and analysis of subjects' feedback and performance under the following sub-sections:

- task completion rates and subjects' perceived overall impressions of the digital libraries
- subjects' perceived impressions of successful implementations of design categories in the digital libraries

4.1 Overall Impressions and Task Completion Rates

Table 2 shows the success rates in completing the 2 tasks by the ten subjects. Table 3 shows subjects' perceived overall impressions of the digital libraries.

Table 2. Task success rates indicating the percentage of users in group that managed to complete the tasks.

Tasks	NCSTRL	ACMDL	NZDL
Search task	80%	0%	50%
Browse task	80%	100%	40%

Table 3. Subjects perceived overall impressions of the digital libraries

Overall impressions	NCSTRL	ACMDL	NZDL
Usability of digital library	100%	100%	30%
Satisfaction when using the digital library	90%	80%	20%
Appeal of the digital library	70%	90%	40%
Flexibility of the digital library	80%	90%	30%
Effectiveness in helping with task completion	80%	70%	50%

Questionnaire results are not surprising. They reinforce the indication that end-users' overall impressions of digital libraries are determined by how effective the digital libraries are in helping them to complete the tasks successfully.

Search
NCSTRL came up well with 80% of the subjects completing the search task successfully compared to 50% for NZDL and 0% for ACMDL. The five subjects who were unable to find the article on "Designing information-abundant web sites: issues and recommendations" by Ben Shneiderman [23] because it was not listed under the appropriate collection but classified as a "technical report". All the subjects were unable to complete the search task using the ACMDL because the article is not published in an ACM affiliated publication. The subjects were generally pleased with the usability of the ACMDL even though they were not successful in completing the search tasks.

Browse
All the subjects were able to complete the browse task using the ACMDL. NCSTRL was also effective in helping the subjects to complete the task (80%). Only 40% of the subjects completed the task using NZDL, and the reason being that the layout is confusing. All links to collections seem to lead to search boxes which produced unhelpful results.

4.2 Design Categories

By analysing subjects' responses under the nine design categories G1 to G9, we wanted to find out whether good design features were perceived by subjects to have been successfully implemented in the three digital libraries. For each question, subjects' ratings were grouped under three categories: "3 and below"; "4"; and "5 and above". Frequencies under the respective areas were obtained. It is debatable but we make the assumption that if an area scores a percentage of 75 and above for ratings given in the "5 and above" category, it implies that, that area is well-implemented in the digital library in question. Table 4 compiles subjects' ratings of the success of implementation of user interface design features of the three digital libraries based on the nine design categories.

Table 4. Subjects' ratings of the success of implementation of user interface design features of the three digital libraries based on the nine design categories.

Design Categories	**NCSTRL**	**ACMDL**	**NZDL**
G1: Overall reactions to digital library	84%	86%	40%
G2: Screen design	62%	86%	47%
G3: Terminology and system information	60%	76%	52%
G4: Learning	74%	90%	62%
G5: System capabilities and user control	80%	74%	80%
G6: Digital library customisation	30%	67%	45%
G7: Navigation	60%	51%	49%
G8: Information retrieval	85%	79%	70%
G9: Completing tasks: Features to help	67%	84%	66%

We will now comment on the usability of each of the three digital libraries:

Networked Computer Science Technical Reference Library (NCSTRL)
Of the nine design categories, only systems capabilities and user control (G5: 80%) and information retrieval (G8: 85%) design categories were rated well by the subjects.

Figure 2 shows part of the NCSTRLs search interface. This page is well laid out and is well designed in terms of the readability of the text and visibility of the status of the system. It provides help and documentation. The information contained in the search page is relevant and dialogues do not contain information that are irrelevant. Instructions to use the search feature is clearly given so end-users' memory load is minimised. A good search feature allows searching to be performed at both general and specific levels. Search results returned also provide links to the document and authors of other works. This is a useful feature providing flexibility and efficency of use.

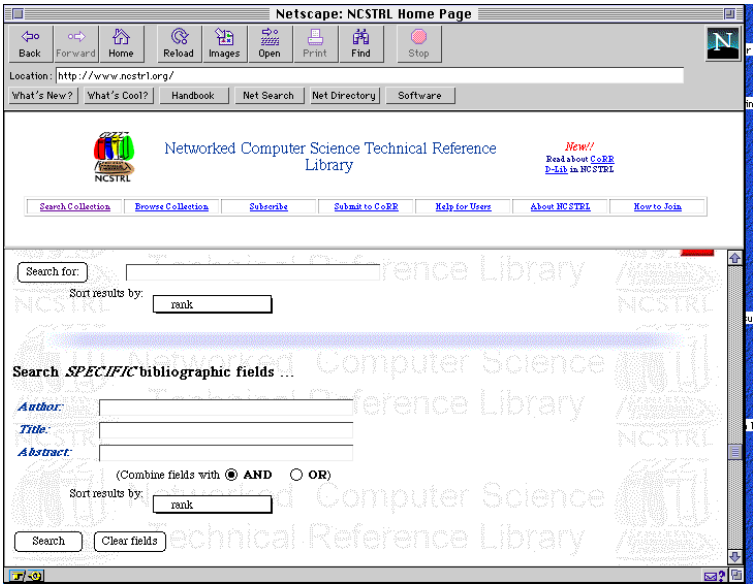

Fig. 2. Screenshot of NCSTRL's search interface

However, NCSTRL does not speak the users' language. For example, the "sort by results" feature has an option "rank" which is unclear as to what it does. The "clear" button does not clear entries for the "search for ALL bibliographic fields". It does not support undo and redo functions well. There is no "exit" button to get out of the search results page.

Figure 3 shows NCSTRL's browse interface. The design of the browse page appears cluttered and the instruction to select the kinds of collection to browse is ambiguous. The scroll window to select the collections from participating institutions is too small making it inefficient to use.

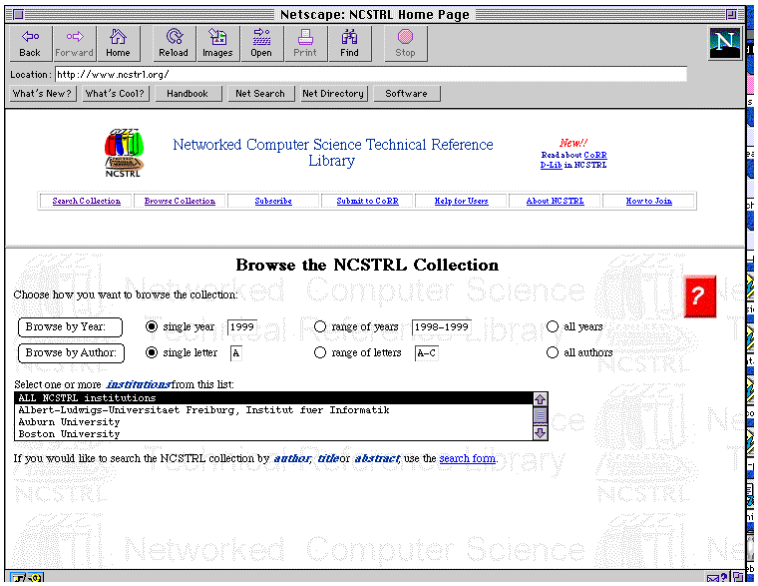

Fig. 3. Screenshot of NCSTRL's browse interface

New Zealand Digital Library (NZDL)

Of the nine design categories, only systems capabilities and user control (G5: 80%) design category was rated well by the subjects. Figure 4 shows part of the NZDL's search interface. The interface design is simple and well-designed. The search function is well-designed, and the search results returned provided a lot more textual formats compared to the NCSTRL's search results. This provides end-users with different views of the documents providing them with flexibility. It also gives the first three lines of the abstracts of the documents to give users some idea of the contents of the documents.

Unlike NCSTRL, NZDL does not have a browse interface. This may restrict flexibility and efficiency of use. The organisation of the collections could be better improved by grouping them instead of providing a list of unrelated options. The icon on "view figures" do not work and no feedback is provided as to why it does not work. Subjects commented that this made searching and browsing difficult. Hence, overall NZDL was poorly rated.

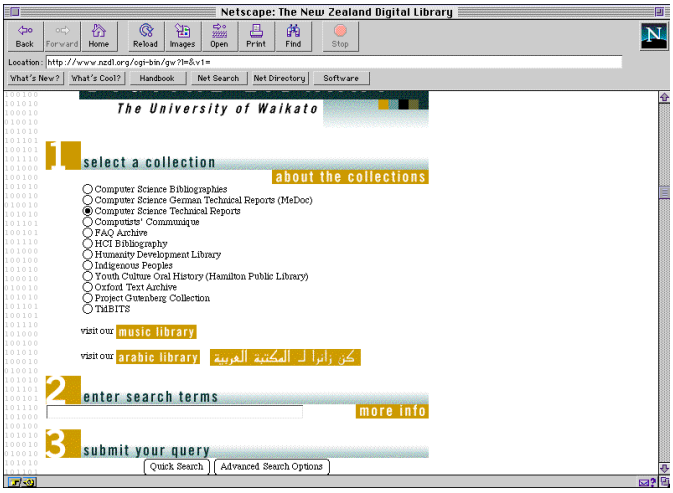

Fig. 4. Screenshot of NZDL's search interface

ACM Digital Library (ACMDL)

Of the nine design categories, only systems capabilities and user control (G5: 74%), digital library customisation (G6: 67%) and navigation (G7: 51%) design categories was rated poorly by the subjects. Of the three digital libraries, ACMDL was perceived by the subjects to be better designed in terms of screen layout, terminology, learning, information retrieval and search features. Figure 5 and 6 show part of the ACMDL's browse and search interfaces respectively.

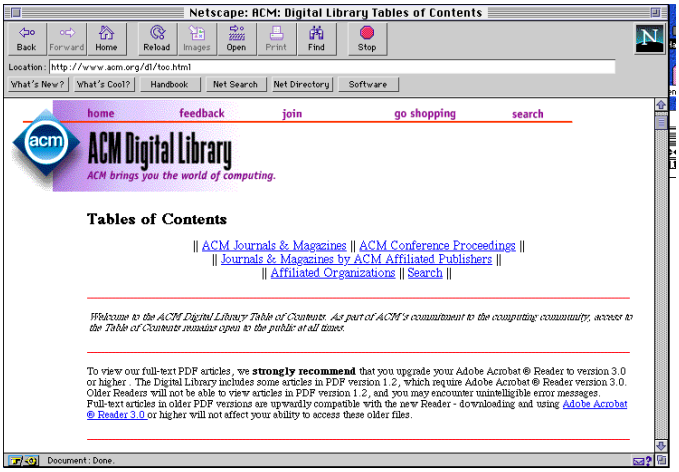

Fig. 5. Screenshot of ACMDL's browse interface.

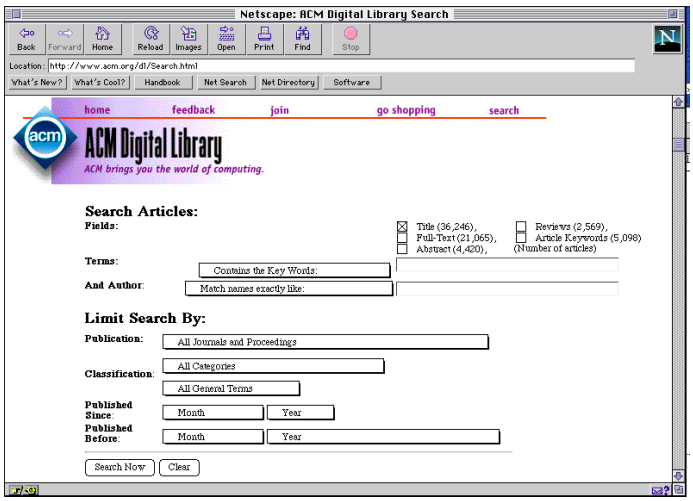

Fig. 6. Screen shot of ACMDL's search interface.

4.3 Further Discussion

Following description of our study, this paper now addresses two areas of design flaws that seemed evident in all three digital libraries:

- *Navigation in terms of end-users' confidence in navigating within the digital library*. From our investigation (see Table 4), navigation within the three digital libraries is still not desirable ranging from moderate 49% (NZDL) to 60% (NCSTRL). The subjects indicated that they experienced some degree of "lostness" ranging from 20% (ACMDL) to 60% (NZDL). We define the "lost in hyperspace" problem to refer to any of the following phenomenon [26]:
  - the problem of not knowing where they are in the digital library (ranging from 30% to 40%);
  - how to get to some other place they know (or think) exists in the digital library (ranging from 40% to 60%);
  - how to return to a topic left previously (ranging from 50% to 80%); and
  - the problem of forgetting the key points covered (ranging from 20% to 60%).

  "Lostness" experienced by subjects can also have a negative impact on subjects' rates of completion [25].

- *Digital library customisation concerning end-users' browsing and cultural needs.* Lack of consideration for end-users' browsing needs ranges from 30% (ACMDL) to 80% (NZDL). The subjects also indicated that the digital

libraries have not taken cultural needs into consideration, ranging from 30% (NZDL) to 90% (NCSTRL and ACMDL). One reason for the neglect of cultural aspects may be that usability failure is rather commonplace, and cultural usability issues are hard to recognise as such, more so since designers cannot help but see the world from their particular cultural point of view. Designers also typically invest a lot of effort getting systems to work at all, and may be defensive about their work. This usually bolsters another cultural barrier, one between professional designers and computer illiterate users or what system designers perceive as such. Thus, cultural usability issues for system designers may come disguised as illiteracy problems or simply as "user faults", rather than as surmountable cultural differences. However, from the above we can conclude that the state-of-the-art digital library interfaces are not yet prepared to fully meet the culturally specific needs of their international users.

5 Design Lessons

Our investigations highlight some ways in which digital libraries can be designed to make them more usable, more adaptive to end-users' browsing and searching needs, and more culturally sensitive.

5.1 Provide Better Navigation Support Mechanisms to address the "Lost in Hyperspace" Problem

To summarise, our brief analysis of NCSTRL, ACMDL and NZDL highlighted a number of points in which digital libraries could be improved. To address the "lost in hyperspace" problem in digital libraries, the best strategy is to consistently apply basic web document design principles on every single page in the digital libraries designers create [26]:

- *Meaningful document header* to identify the content of the document.
- *Text-labelled navigation aids* to indicate clearly their functions.
- *Page footer* to identify the origin, authorship, author contact information, date of creation, copyright info, etc.
- *Sensible page length* to prevent as little scrolling as possible.
- *Clear use of language* to prevent confusion.
- *Simple features* (not flashing and fancy ones) to make reading easier.
- *Hypertext links*. End-users can move to related information by clicking onto hypertext links, represented by underlined text or figure. Hypertextual links should be embedded in the documents to provide end-users with the ability to move to related information quickly without having to waste time submitting another query and waiting for the query results. Links should provide a prospective view. Before end-users make the jump, they are given prospective information about the destination node (URL with path and filename) provided in

the footer. It would be helpful to end-users to provide them with the abstract and/or outline of the document before they make the jump.

- *Bookmark*. End-users can build a set of direct jumps to their favourite places in hyperspace using bookmarks.
- *History list*. End-users can go back to previously visited web pages since the start of the session using a generated history list.
- *Index / table of contents*. This provides end-users with an overall view of where they are to prevent disorientation.

5.2 Provide Workspace and Equal Opportunity for More Flexibility and Manipulation of Search Results

If digital libraries are to be user-centred, there is a need to make them adaptive and adaptable, taking into consideration end-users' needs and browsing patterns [2]. Cockburn and Jones propose building a graphical browser that dynamically adapts to, and reinforces, end-users' browsing actions and mental models [6]. Efficient search and linking facilities should be incorporated within digital libraries. One of the biggest challenges in the digital libraries is finding something specific since there is so much information available. On-going research is conducted to provide more accurate, faster and more efficient search and linking facilities on the web include automating indexes (such as web robots or spiders) to walk the entire server tree, text compression techniques, machine learning techniques, *etc*. Examples include:

- Meta-search engines (for example, MetaCrawler Parallel Web Search Service; SavvySearch; ProFusion, *etc*.) use multi-threaded query gateway to query multiple search engines (for example, InfoSeek Search; Lycos; WebCrawler; Web Worm; JumpStation, *etc*.) simultaneously [10].
- The New Zealand Digital Library for Computer Science uses modern compression techniques to provide access to over 10 000 documents worldwide in computer science, and makes them available over the web through full-text interfaces [27].
- DEC's Library Information Access Client supports a card catalogue metaphor and represents individual searches as objects that can be moved and stored. The search results are colour-coded to let end-users know which results go with which searches [22].

It is important to have effective search engines, but as Agosti, Gradenigo and Marchetti [1] argue, it is important to properly represent the results to users. However, Harman [9] argues that we need more than just "user friendly" front ends. The whole system must be designed for usability.

The problem with the search facilities provided by NCSTRL, ACMDL and NZDL sites was the lack of a facility to manipulate the search results independently of the search mechanism itself. This had practical repercussions. For example, in the NCSTRL library one subject reported that they were able to discover result sets of different sizes (54 and 67) on the same search item, but was prohibited from sorting the larger set, as it was not created directly from the search mechanism, but instead by clicking on the author name in a result set (searching on the same data yielded yet

another result set 175 but that was clearly too general). Also, in all the libraries the only way to return to a search result set was to re-execute the search, or use the browser "back" button to return to it. Rejected items are still included, and no indication of value is given to selected items.

It may be useful to compare this to the opportunity of activity in a traditional library. Here, readers are able to get a list of possible items of interest, and retrieve them for further inspection. Those which prove of cursory interest can be set aside or returned to their usual place quickly, and those of greater use can be gathered together for deeper investigation.

A comparison can easily be drawn between these work patterns and the principle of Equal Opportunity introduced as a heuristic for human-computer interaction [21]. Here, the user can exploit the prior output of the computer as input to a further stage in interaction, with or without modification.

If we thus introduce to the digital library facilities a "desk" for interaction on the basis of Equal Opportunity, the reader of the library gains the opportunity both to mirror real world behaviour, and to interact effectively with additional digital facilities in the same domain. For instance, discovered items can be collected, ordered, prioritised, remembered, etc within the digital library space. More concretely, in the example above, the larger output set could be selected, and then reordered using existing facilities, making the provision of effective support for the reader more complete.

5.3 Provide Culturally Sensitive User Interfaces

To provide multi-cultural interfaces to digital libraries, we envisage the development of boundary objects between different cultures accessing shared information resources. Boundary objects organise shared but simultaneously distributed cognition. Boundary objects are used by different communities without presupposing a fully shared definition of an object. They are flexible enough, such that each community can read a specific meaning from a boundary object sufficient to its needs. Simultaneously, they are "robust enough to maintain a common identity across sites" [24]. As such, they enable collaboration and communication across cultural boundaries on equal terms, for example, without recourse to a single-sided dominant mode of symbolisation.

Boundary objects function between human cultures in much the same way that module interfaces separate implementation concerns in programming, but nevertheless allow modules to communicate without accidental assumptions causing trouble. To achieve the emergence of inter-cultural boundary objects in digital libraries, co-operative and communicative features need to be introduced that allow negotiation and articulation across sites.

We offer some ideas for implementation of boundary objects in three areas:

- *Creation of boundary objects as part of the digital library interface*. Actually, a digital library system with perfectly localised interfaces could function as a joint composite boundary object. However, small boundary

objects and shared resources could start off a process of mutual cultural education between users, designers and content providers. The introduction of asynchronous message systems, repositories and frequently asked questions (FAQs) could serve such a function because it allows users, designers and content providers to quickly exchange information. Another idea is to build *graphical browsers* that rely on dynamically generated structure maps that adapt to end-users' needs and come in various forms [16]: *global* maps show the entire hyperspace; *local* maps show the "vicinity" of the current node in terms of hyperlinks to and from other related nodes; and *fisheye* views focus attention on important nodes by deliberately distorting the view.

- *Creation of a learning environment*. The emergence of boundary objects depends on mutual education of the participants. Therefore, in digital library interfaces, a learning environment is necessary. In order to create a learning environment, we need to provide additional facilities that help end-users, content providers and designers in fulfilling their tasks or even to provide intelligent intermediaries to do the tasks for them. In conventional libraries, the provision of this kind of support is the helpdesk manned by a librarian. While helping the users to find information by doing things for them, the librarian is also often surreptitiously teaching the users how to make the best use of the library. As a result, users are able to do at least part of the task on their own. Simultaneously, the librarian learns about the interest of the users. Often the support from librarians is augmented by the provision of support from user to user. More experienced users can offer informal help and advice to novice users. In creating such a learning environment for end-users, we should provide suitable support features when collaboration between users is most effective. The construction of Community Memory Support Systems like Answer Garden and FAQ lists will allow end-users to gain an understanding of how systems can be used.

- *Creation of opportunities to create boundary objects by users*. Even the best designer cannot foresee all cultural problems and possibilities. The idea, therefore, is to create opportunities for end-users to create boundary objects. Giving end-users the opportunity to articulate and exchange their ideas and problems with regard to a particular digital library may also provide surprising ideas that could be taken up by designers. Awareness mechanisms have to be developed that will allow end-users to be aware of when others are accessing the same resource. The use of synchronous co-operative support tools like Chat Rooms and Meeting Rooms will allow end-users to discuss and debate different approaches to accessing the on-line resources. The core use of these tools is to support the co-operation and debate needed to resolve decisions. To help end-users tackle the problem of information overload as well as not to be "lost" in the wealth of information available, we suggest the use of interface agents in digital libraries to make them more adaptive to end-users' needs. Interface agents make software more active and work autonomously without waiting for end-users' command. One example

of the use of software agents in digital libraries is the investigation of personalised information filtering systems to help end-users to eliminate irrelevant information and bring relevant information to end-users' attention [15].

6 Conclusions and On-Going Work

In this paper, we carried out a study to investigate useful design features digital libraries should have. The study provided insights on the usability impact of digital libraries for task completion and end-users' perceived impressions on the effectiveness of the digital libraries. We discussed design guidelines for the design of user-centred digital libraries. This is on-going research for us. In order to achieve our goal to define a set of principles for the design of digital libraries, the design features discussed in this paper need to be further refined, tested and used in real-world situations before they can emerge as principles for design of user-centred digital libraries.

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