Designing Virtual Environments to Support Cooperation in the Real World

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Abstract. Much of the current research in the design of virtual environments is centred on laboratory prototypes and emphasis is placed on supporting cooperation within the virtual world itself. By way of contrast, this paper places an emphasis upon the development of virtual environments that support cooperation within the real world. This external research focus situates virtual environments within the bricolage of material artefacts that people use in coordinating and accomplishing ordinary jobs of work. We elaborate the shift to the external environment of ordinary human jobs and users through an ethnographic study of searching for information in a library, and the design and evaluation of a prototype supporting the real world cooperation involved in getting the job of searching done.

Keywords. Virtual environments, material affordances, cooperative work, ethnography, design, evaluation.

1. Introduction

Cooperation is a central topic of virtual environment (VE) research, where the emphasis has largely been placed on supporting human-human interaction within the virtual world. This paper, by way of contrast, places emphasis on supporting cooperation in the real world. Recognition of the need to attend to the real world demands of cooperation when undertaking VE design is not new (Bowers *et al.* 1996) and more recent research draws attention to the need to augment the artefacts related to the work of users in particular (Büscher *et al.* 2000). This shift to the external world of material resources is driven by recognition of the grossly observable fact that when people work together, they do so through the use and manipulation of a vast array of artefacts. Thus, the research challenge for VE design is expanded to address the development of support for cooperation in the real world through the augmentation of material resources with which people conduct their work together.

With this objective in mind, we consider the development of a VE supporting cooperation in a particular real world setting: the library. Previous research has conceived of two broad classes of potential VE use: simulations or facsimiles of real world environments, and abstract environments that help users make sense of online information (Frécon and Smith 1998). The library setting was chosen, then, as it allowed us to explore the research challenge in relation to the design of abstract environments.[1] More specifically, developing support for library users allowed us to explore the potential to improve the discovery of information in general, which researchers have offered as a potential benefit of VEs and 3D visualisations (e.g., Chalmers 1993; Mariani *et al.* 1995; Mackinlay *et al.* 1995). In undertaking the research

[1] See eSCAPE Deliverable 4.2 (1999) for exploratory work in facsimile environments.

challenge we also wished to understand something of the process by which abstract VEs may be designed to support cooperation in the real world. Accordingly, we outline the results of a number of ethnographic studies employed in the development of an abstract environment to support searching in the library. We provide an overview of the application produced in light of the studies before considering the impact of evaluation sessions conducted with end-users.

2. Developing Virtual Environments Supporting Cooperation in the Real World

Ethnographic studies were employed to identify real world constellations of cooperation and assistance that might benefit from technical support. The ethnographic findings reported here were drawn from a previous in-depth six-month study of a diverse range of search activities commissioned by the British Library. The study was conducted between October 1997 and May 1998 at a University library in the UK. Over forty individual studies ranging between one and three hours were conducted during that time at various sites around the library. Parties to the studies included both novice and experienced library users having a wide range of practical concerns (covering the arts and humanities, science, and personal interests), and novice and experienced library staff (ranging from trainees, to help desk staff, to specialist subject librarians). The studies addressed a wide range of topics including, online public access catalogue (OPAC) use, WebOPAC use, CD-ROM use, use of the physical catalogue, user-user collaboration, user-staff collaboration, and staff-staff collaboration. The findings presented here are *selective*, being relevant to the technological issues we address.[2] Although ethnography is one of the oldest methods in the social science research armoury, the rise of logical positivism and quantification marginalized the approach

[2] The wider body of findings is reported in Crabtree *et al.* (1997), Twidale *et al.* (1997), Crabtree (2000), Crabtree *et al.* (2000), and research reports of the EU Esprit Information Technologies Programme long-term research project eSCAPE (http://escape.lancs.ac.uk/).

under contestable auspices of scientific measurement (Winch 1988; Hughes 1993; Benson and Hughes 1991). Nonetheless, the approach has enjoyed a resurgence in a design context, where it has proved to be a viable means of informing requirements analysis of the social circumstances of system usage (Grudin 1990; Goguen 1993; Hughes 1994). Ethnography elaborates those circumstances by attending to the talk that occurs in a setting and describing the practical actions and interactions (or cooperative work-practices) whereby the setting's activities are observably assembled and organized by parties to their accomplishment (Button and Harper 1996). Transcripts of talk in the library are provided below to elaborate the cooperative work involved in the accomplishment of particular search activities that the technology was designed to support.

Ethnographic studies suggested that OPAC works well in situations where users know what it is that they are searching for. OPAC systems are considerably less effective, however, in situations where users do not know in advance just what information will satisfy their requirements but are guided by a vaguely defined topical interest (Twidale *et al.* 1997). This particular finding suggested that we might explore the research challenge through developing support for topic-based searching. That is, for search situations in which users do not know in advance just what it is that they are looking for – a very common feature of searching in library and beyond, which often occasions cooperative work (Taylor 1968; Fischer and Reeves 1992; Crabtree *et al.* 1997). In order to devise support for the cooperative work implicated in topic-based searching we examined the ethnographic studies of work to identify significant cooperative and materially-bound working practices through the accomplishment of which searching is routinely conducted by library users.

2.1 Cooperative Practices of Searching in the Library

A user's first point of entry to the library catalogue in undertaking a search is, more often than not, through OPAC. OPAC provides a 2D interface to the catalogue which offers users a list of options whereby they can initiate a search and browse the catalogue's contents. When undertaking a search, users orient to and employ these options as elementary categorisation devices that allow them to fit their query into the catalogue. Thus a user searching for items on a reference list, such as *Object-Oriented Analysis and Design* by *Martin and Odell*, for example, selects the author-title search option, categorising the search in a very specific way (title or keyword could have been selected instead). As simple as this fitting work may sound, in practice its accomplishment is often a practically troubled affair. Consider the following fieldnote extract, for example.

Ian initiates an author-title search - Rutter, M / Fifteen Thousand Hours

25. Ian: Now if this bugger's not in here I'll eat my hat even though I haven't got one.

Ian executes a search, looks at the display and sighs

26. Sam: You're joking - it might be further up.

Ian scrolls back one display

27. Ian: I don't believe that ain't in - it's got to be in!

42. Ian: When I did that Rutter one, did I try that on the title?

43. Sam: Tell you in a minute (checks his notes).

44. Ian: ‘Cause I can’t believe that’s not in.

45. Sam: Fifteen thousand hours - author-title you did.

46. Ian: Right, try that on title then.

Ian initiates a title search - Fifteen Thousand Hours: Secondary - the item is N$^{o.}$ 1 on the retrieval list

47. Sam: Got it?

48. Ian: Twelve copies!

As the talk makes available, even in situations where what is wanted is known in advance, users coordinate their search activities through the use of material resources to hand (reference lists, notes, and especially OPAC itself) and do so in a particular arrangement of *shoulder-to-shoulder* cooperation that take place around OPAC. It is also worth noting that as contingencies demand, users draw directly upon *their previous search history* to formulate an appropriate query so that it fits into the catalogue in a productive way. In formulating the fit the search is constructed by users through the use of particular material resources, then, which are routinely employed, by users working in concert towards the end of locating particular items in the catalogue.

When users do not know in advance just what they are looking for they face a more troublesome situation. In this case, shoulder-to-shoulder cooperation involves formulating a *practically adequate* fit. Thus users work together to formulate search descriptions that will produce appropriate search results, and particularly descriptions that produce manageable results:

55. Sarah: I don’t really know what I’m doing.

Sarah types in stress – gets 1167 hits - looking at the screen

56. Lucy: Stress and causes isn't it?

Sarah types in stress and causes – gets 5 hits.

Failing the adequacy of shoulder-to-shoulder collaboration between users, help desk staff and subject librarians may be consulted (or the search abandoned). Consultation with library staff is similarly concerned with making the user's query fit the library catalogue through a course of categorisation work (Crabtree *et al.* 1997). Searching is, as such, an essentially cooperative achievement concerned, as a matter of mundane routine, with the effort to work up search categories that will produce practically adequate results in and through the use of OPAC and the other resources to hand. Manageable results in hand, users (and help desk staff or subject librarians) undertake the next activity in the accomplishment of searching, namely *identifying potentially suitable items*.

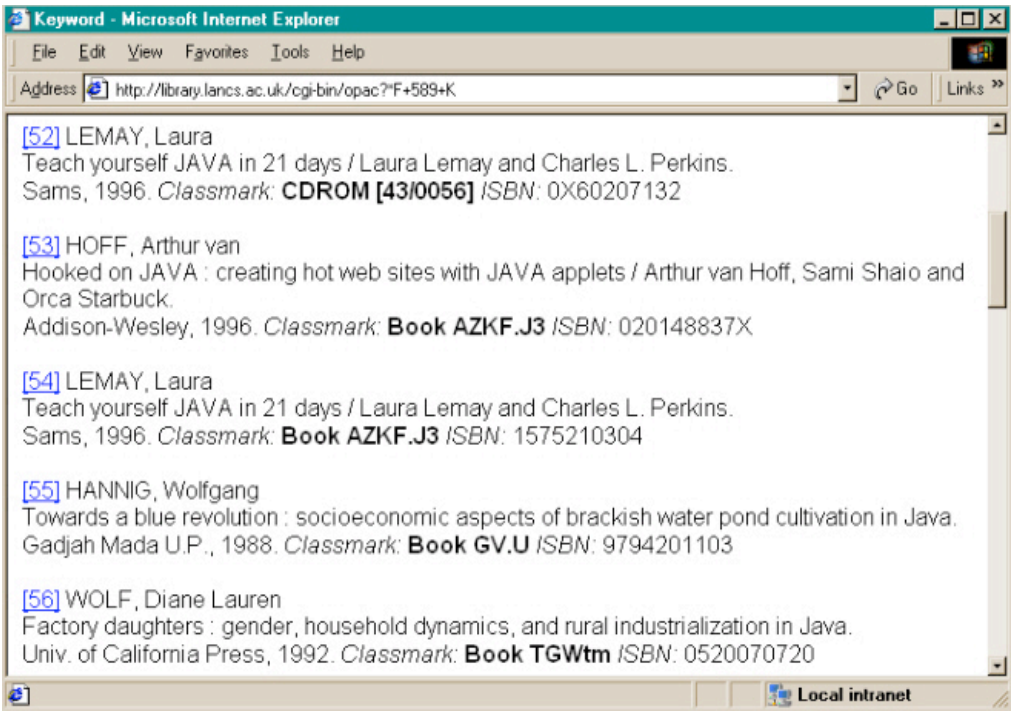


Figure 1. The OPAC user interface – a random list of topical items

Having formulated a practically adequate fit, OPAC displays a list of results. The type of list returned varies according to the search issued: some offer topical groups, others

individual items. The user selects a topic or a particular item. In selecting a topic, a list of randomly related items is returned and displayed. As Figure 1 makes visible, in doing this users are, in effect, presented with an array of topics. In doing a topic-based search on java, for example, items are returned not only on computer programming, data structures, algorithms, and the rest, but also on java the island, its flora and fauna, and a host of other topics. Users have a great deal of work to do, then, in finding something of personal relevance. That work consists of browsing the list and *evaluating* particular item titles in doing so – a very time consuming and laborious activity insofar as large searches are concerned.

The work of evaluation is conducted through reading an item's titles for its relevance to the search and, thus, to establish a sense of the item's potential suitability. If a particular item "sounds interesting", users may select it for viewing. Selecting a particular item produces a further display. Here, particular bibliographic details are relayed to users. Should the item transpire to sound (potentially) suitable, users check the display to ascertain its availability, write down the item's classmark if the item is available (and one or two other details such as author and title), and set off to retrieve it and any other items identified as potentially suitable. Notably, identifying potentially suitable items is based upon *seeing the sense and relevance* of items displayed on retrieval lists, and their *relation to other similar items* that are located around items previously identified as potentially suitable in the physical library itself. The potential value of an item or collection of items is not immediately available within the current interface and users are therefore obliged to undertake considerable work in order to identify items of interest, both in terms of browsing lists and scanning books on shelves in the physical space (Crabtree 2000).

As noted above, users often experience practical troubles in finding potentially suitable items when conducting searches and turn to each other or staff for assistance. We have already seen in the first sequence of interaction the importance of history. The following fieldnote extract illustrates the ways in which help desk staff deal with user's search troubles as a routine matter of cooperative work.

16. Librarian: (Has issued an OPAC search and is looking at the list retrieved) Is it marketing intelligence and planning? Is that the one?

17. Librarian: T6 – it's a journal.

18. Sarah: No. It's not a journal.

19. Librarian: Do you want to check at that and find the journal itself?

20. Sarah: Been there.

21. Librarian: But have you actually looked at the classmark?

22. Lisa: Yes.

23. Sarah: Yes.

24. Librarian: You've looked at that and it's not what you're looking for?

25. Sarah: It's not what I'm looking for.

28. Librarian: You've checked in the reference area?

29. Lisa: Well, no.

As a routine matter of work, help desk staff manage practical troubles occasioned in the search for potentially suitable items by appealing to user's search histories. Elicitation of users' search histories serves to make explicit or spell out in detail just where users have been and just what they have looked at. The search history is employed by help

desk staff both to eliminate areas of the search and, alternatively, as in the case above (as is so often the case), to furnish new resources with which *to elaborate and refine the search* (that potentially suitable items may well be located in the reference area, for example). In the case above, and as a result of administering the procedure, staff took the users to the reference area and quickly located items that satisfied the users information requirement.

Once again, the current interface does not make search histories available to users. Neither does the interface provide the opportunity for the prior activities of other users to inform users in their current search activities. Prior search activities enter the search by word of mouth and in that respect users encounter the activities of others serendipitously. By undertaking ethnographic investigations of the material working practices of users in the library and the limitations of the technology employed, requirements for technical support were identified however. Design was therefore directed towards augmenting OPAC in ways that would support existing arrangements of shoulder-to-shoulder cooperation involved in topic-based searches, supporting the working up of search categories, enabling users to see the sense and relevance of search items, and the helping users elaborate and refine a search through the use of previous search histories.

3. The Developed Environment

The studies of search described above were employed to ground design in an actual use practice, being used in particular to formulate use scenarios (Kyng 1995). Use scenarios serve to shape design, sketching out and setting targets to be met in the formulation of potential design-solutions. The use scenarios formulated by the ethnographers and

designers of the developed environment specified the design of a prototype that provides two distinct forms of support.

- *Topic-based support* where users and staff perform categorisation work together in order to identify potentially suitable items.

- *History-based support* where users exploit previous search activities to identify alternative search topics, keywords, and items.

In constructing the VE we exploit DIVE (Carlsson and Hagsand 1993) and DEVA (Pettifer and West 2000) and Q-pit visualisation techniques (Mariani *et al.* 1995). The developed environment connects to the library's WebOPAC, which allows remote access to the library catalogue. The environment draws upon both the catalogue and a collection of OPAC searches issued from all users of the system. These two information sources are used to produce two distinct yet coupled displays.

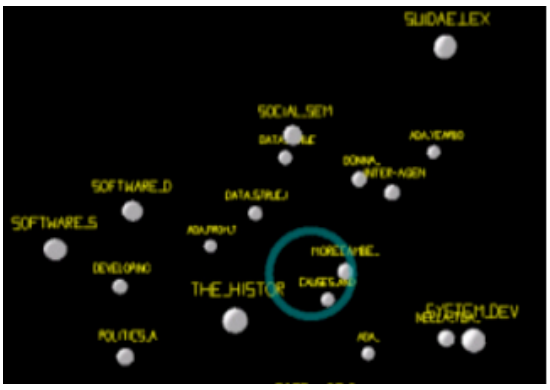
- *The category display.* This presents the information in the catalogue as a series of linked structures allowing users to undertake the categorisation work outlined in the previous section, and to do so at-a-glance (in contrast to the laborious reading of lists).

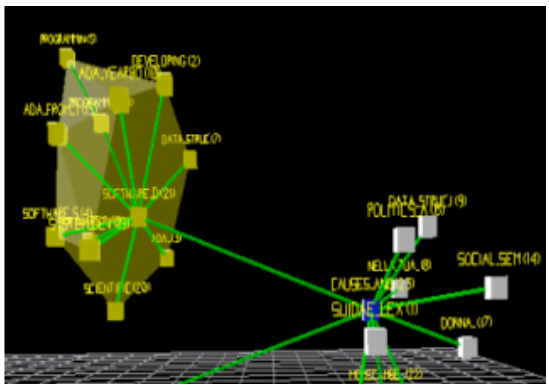
- *The activity display.* The aggregate effect of previous searches by other users is used to drive a display that makes recommendations of appropriate alternative search topics.

These two displays share a common repository of information and are linked to one another, allowing effects in one display to be reflected in the other. In the following sections we provide a brief overview of the two displays and outline how each presents different aspects of OPAC information and use to users.

3.1 The Category Display

The central interface for our virtual OPAC environment is the category display. This presents a 3D information landscape constructed from an analysis of the contents of the OPAC database. Users initiate an exploration of the search space by entering a keyword into a single keyword entry window. This is analogous to the topics used as a starting point by users when they cluster round the OPAC. This topic has a specific vagueness in that it outlines a general area of interest as a starting point for exploration but little more than that. By way of supporting users in producing answers to this form of query, the items that match the keyword input by the user form the basis for the generation of a category display. The OPAC is searched using the keyword query and the returned objects are then used to populate the space making up the category display (Figure 2.1). Retrieved objects are first 'spat out' into the space, giving the users a feel for how many objects have been returned as part of the search. Regions of similarity are then identified and a regional colour associated with each item accordingly. A force-directed placement algorithm is then applied and the coloured objects begin to swarm together into coherent, coloured groups. The clouds display at-a-glance groupings of similar objects. The links point out interconnections between clouds and objects therein (Figure 2.2).





Users can see at-a-glance just what each cloud contains as a topical space. In issuing a keyword search on Ada, for example, the user can see that the cloud in (Figure 2.2) contains items on the programming language and software engineering. This is linked to a cluster of objects focusing on people called Ada, including Ada Lovelace who the programming language is named after. This visualisation of the grouping provided by the category display provides users with an emergent sense of categorisation. The category display represents an exploration of a radically different interface than the text-based OPAC display currently provided to users. The formation of the space is motivated by the need for a flexible material resource allowing users to coordinate their search activities in the course of formulating a practical adequate fit. The category display also allows users to build a printable shopping list of books in which they are interested. This list can persist across different searches and is, as such, session-oriented and linked with particular users (thus supporting appeals to the history of particular searches).

3.2 The Activity Display

The category display reflects the focus on the use of emerging information categories and aims to support cooperation between users sharing a public access point to the catalogue. We are also interested in exploiting the previous activities of users. As we saw in our studies of the library, helping users search the catalogue drew upon the

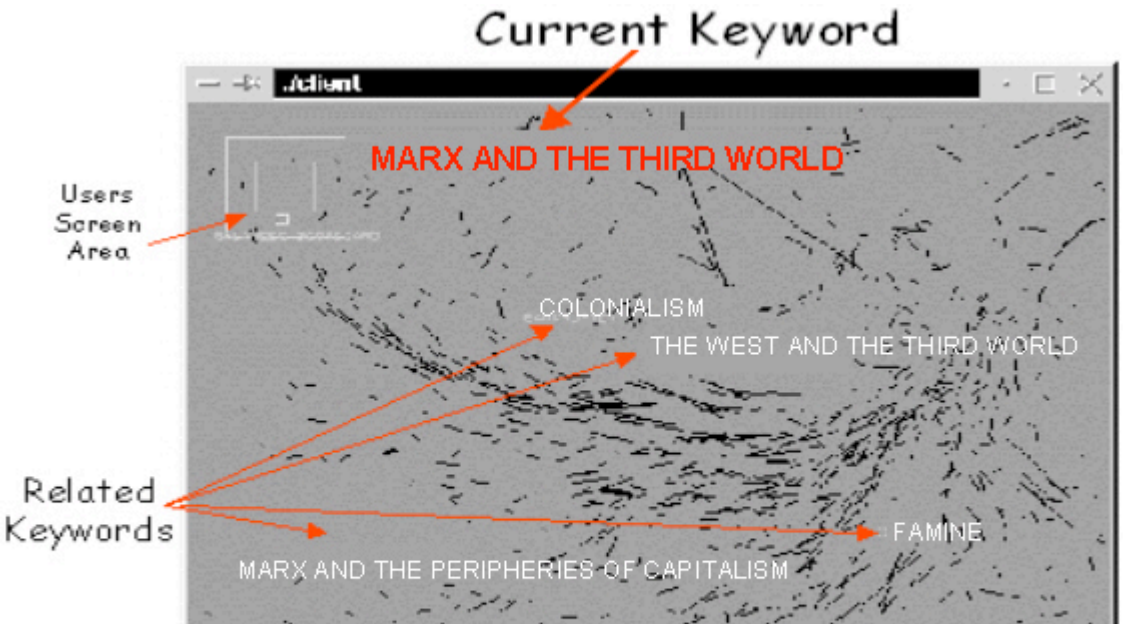
history of search activities previously undertaken. To support this approach to finding information in the library, we complement the category display with a display that makes the online search activities of the entire community of users available as a resource. The aim here is to allow searching to be supported by providing a sense of cumulative and aggregated social interaction with the environment.[3]

The starting point for our consideration of the use of search histories focused on the identification of search trails as a means of representing previous activities. Our use of search trails builds upon the notion that sequences of search activities make distinct paths through an information space (Chalmers *et al.* 1998). Essentially, we can consider people forming a trail through the information repository as they uncover objects and that this trail provides a resource for other users to make sense of the overall information landscape (eSCAPE D4.1, 1999). The aim here is not to provide an exhaustive topography of user search trails but rather to provide an awareness of the cumulative sense of social activity in searching, with specific reference to the interactions of community members with particular contents of the library catalogue. This approach mirrors that of BABBLE (Erickson *et al.* 1999; Bradner *et al.* 1999) where an aggregated display is employed to convey awareness of the activities of other people as understood from the point of view of their interactions with the technology to hand. Thus, the activity display highlights and suggests areas of the library catalogue of potential interest to users by drawing their attention to areas that have been investigated by other users issuing similar searches. In a manner akin to recommender systems (Malone *et al.* 1987; Resnick and Varian 1997), which are of increasing interest to the

[3] The word 'social' here draws attention to the prior interactions of members of the user *community with the contents of the library catalogue*, rather than the interactions of members with each other.

digital library community (Chalmers 2001), the aim here is to exploit the search activities of previous users as a means of suggesting items of potential interest to current users.

The activity display was adapted for the above purposes from a multimedia art piece provided by project partners (Schiffler and Schwabe 1998). The choice of display was purely pragmatic, shaped by available resources rather than previous work on visualisation in the library. Nonetheless, the art piece provided a tried and tested visual display that allowed the relationship between different entities to be represented to users via animated clouds (Figure 3). Entities in the display are continually rearranged using a self-organizing algorithm that makes search terms and trails cluster together. The density of the interrelationship provides an impetus for users to investigate particular areas of the display. Whenever the user enters a new search term in the main query window the visual client is updated and centred on the cluster of trails associated with the search term through the previous interactions of other users with the catalogue. Related clusters of search terms are visible in the immediate neighbourhood. The user can choose to select a cluster by moving the mouse over the text label and clicking on it. This action initiates a new OPAC query, which then updates the category display and redraws it based on the new keyword.



4. Situated Evaluation of the Developed Environment

Having designed what to us seemed like a coherent artefact, the next question to be addressed was whether the demonstrator would be experienced as coherent by users. Working on the assumption that library users are the real experts in the accomplishment of searching, the prototype was made available to end-user experimentation (Bødker and Grønbæk 1991) and its use subject to Situated Evaluation (Twidale *et al.* 1994). By 'end-user experimentation' we do not refer to the kind of lab-based evaluative exercises that characterise HCI. Rather, we refer to the Cooperative Design of computer systems in which prototypes are made available to end-users and their hands-on experiences are used to elaborate, in an iterative and incremental fashion, requirements for a future system-of-work. Cooperative Design is, then, a distinct approach to the construction of prototypes that repositions evaluation to assume a formative part in an evolutionary process of design (Bødker and Grønbæk 1991).

The formative use of evaluation is underpinned by three notable criteria (Mogensen 1992).

- *Seeing the sense of the artefact***.** On encountering a prototype, users can rarely see the sense of it. It is not, at first glance, intelligible to them and its potential use must therefore be explained. 'Explanation' here consists of showing users how to use the instrument to do a real job of work (doing topic-based searching in this case).

- *Recognising the relevance of the artefact***.** That users may see the sense of the prototype – what it is intended to do and how - does not mean that they will recognise it as relevant to their work. If users are to engage in any meaningful analysis of the prototype's potential utility and elaborate further requirements they need to be able to recognise the relevance of the prototype to their work. The recognition of relevance may be engendered through hands-on experience.

- *Appropriation of the artefact***.** Users may appropriate a prototype that is recognised as relevant to their daily work. Appropriation involves preliminary acceptance of the prototype as a viable socio-technical system of work. Appropriation provides a concrete basis for the development of stable evolutionary prototypes.

In evaluating the prototype we have married cooperative prototyping with Situated Evaluation. Situated Evaluation is expressly concerned with the efficacy of the prototype not as an internally coherent technical artefact but as instrument supporting work activities as they are performed in the real world. As Twidale *et al.* note,

"This shift in emphasis away from the system as a technical artefact towards the system *at work* has a number of important implications for the evaluation process, implications which place ethnographic insights … at its centre, at least if system 'validity' or 'acceptance' is the problem being addressed." (Twidale *et al.* 1994, p. 450)

We employed ethnographic insights (i.e., work studies) to establish the validity of the prototype, where validity is understood as the prototype's ability to support or augment the real world, real time cooperative work of users. The validity of the prototype is established in the first instance by the ethnographer, who employs studies of work as a means of assessing the *prima facie* work-ability of the prototype. In the second instance, the validity of the prototype is established in prototyping sessions with end-users, who employ the prototype to do their ordinary jobs of work (searching, in this case). Prototyping sessions are not treated as experiments in a scientific sense of the word then, but as sites of work where the work-ability of the prototype may be experimented with, assessed, and elaborated in direct relation to the practical purposes of the job to hand. Such experiments are practical through and through and in such detail (as we address in the following section) inform future design activities.

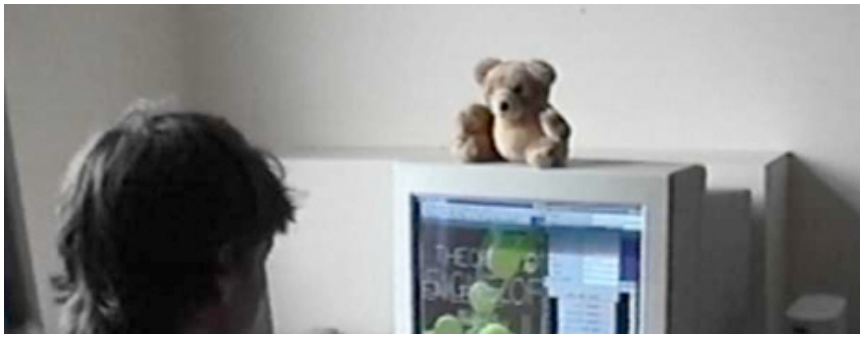
There is, of course, nothing new in taking a pragmatic approach to evaluation – usability trials have long treated prototyping sessions as sites of work that may inform design. In such cases, however, analytic attention is usually accorded exclusively to the user (Grint and Woolgar 1997). In conducting Situated Evaluation of Cooperative Design sessions, analytic attention is accorded to the work that makes the technology work *in situ*, and that includes the work that takes place between users and designers. In such a way the glitches, breakdowns, troubles, repairs, and the rest of the work it takes

to make the technology work and get the ordinary jobs of users done (work which is usually ignored and otherwise discounted as mere noise) is taken into account in design. The significance of such an account lies in the simple fact that 'that' (i.e., glitches, breakdowns, troubles, repairs, and the rest) is just how the technology came to be used really and much may, therefore, be learnt from 'that' work.

4.1 Learning from the Cooperative Work of Users and Designers

The prototype was made available to end-users in a variety of settings ranging from public exhibitions to small workshops involving academics, students, and administrative staff that needed as part of their day's work to search the library in order to find particular resources. The point and purpose of evaluation was to establish whether or not the prototype supported current arrangements of cooperation, and to elicit a tangible sense of what more may be done in terms of designing for future work practice (eSCAPE D4.1, 1999). Evaluation proceeded in demonstrating the prototype, then getting users to do the work activities the prototype was designed to support, in contrast, for example, to the doing of abstract tests to establish the validity of the technical system or certain aspects thereof.

Users were quick to see the sense of a 3D environment populated by clustered arrangements of related objects and, in undertaking exploration of the environment, readily recognised the relevance of the prototype to the accomplishment of search activities. Further still, and as the following extract makes clear, the users were quick to appropriate the prototype for their practical purposes.



1. Vince: How about juvenile delinquency? I've to find a video for the prison tomorrow any way. (Vince issues a search query).

2. Tina: (Looking at screen) That's nice.

3. Vince: Yeah. Right - well let's start. (Starts navigating clouds). Alright, so blue is - book. OK. Alright.

4. Claire: What's green there?

5. Simon: Green and grey.

6. Vince: Pamphlet. OK, we're doing fine.

7. Simon: Oh - you got reds up there.

8. Vince: Yeah. Yeah. There we go (selects an object for viewing). OK (reads title). No.

9. Vince: I like this 3D thing actually - this is pretty cool. (Browsing around the items in a cloud). What have we got down here?

10. Vince: There we go – signs of the troubled aspects of delinquency. OK, I might actually write that down. (Vince writes the classmark and title of the video down on a notepad).

As the vignette clearly indicates, users worked together around the screen as they did when using the OPAC system and both engaged in and accomplished the work activities they were familiar with in coming to understand and use the environment.

That the VE was well received does not mean that a perfect piece of technology had been developed, however. On the contrary, users identified a number of practical shortcomings in their efforts to accomplish searching. In the course of the evaluation a number of practical troubles emerged which placed various constraints on the development of the prototype. That is, troubles emerged that shaped design in specifying concretely just what the demonstrator should support from the perspectives of various users *engaged in* searching's work. Several illustrative examples are outlined below (for a thoroughgoing account see eSCAPE D4.1, 1999; eSCAPE D4.4, 2000).

- *Spatial distribution of objects.* Perceptual troubles were experienced in densely packed clouds. Users found it difficult to discern particular objects, as they overlapped and obscured one another. The problems here resulted from the spatial distribution of objects. The dense grouping of objects is not efficacious from a user's point of view and needed some rebalancing (a non-trivial matter of devising appropriate placement algorithms).
- *Re-locating objects.* Difficulties emerged in the course of trying to re-locate particular objects that users had previously identified as useful. Insofar as the problem was resolved during the evaluation then it was through the collaborative efforts of the users in retracing steps taken. This suggested the need to devise a history function supporting current searches.

- *Object titles.* The display of text is notoriously difficult in VEs and in the developed environment this was not provided in full. However, an item's title was seen and understood by users as the primary resource employed in establishing its potential relevance to their information requirements. Full text would be required then.

At the same time as users identified a number of mundane but nonetheless *critical* practical troubles that shaped subsequent development, a number of possibilities for design also emerged. These were not related to particular problems as such, but concerned functionality that users felt it would be good to have. Users articulated these (and again we only provide one or two illustrative examples here) as they worked with the developed environment to undertake real world searches of the online library catalogue.

- *Browsing classmark relations.* Having located an object of potential relevance through searches not based on classmark, users nevertheless thought it relevant to be able to browse the other objects within the same classmark without regenerating the space; the rationale being that such items will be 'about' similar sorts of things. Users wished to make this form of browsing immediately available to themselves and others working alongside them.

- *Support for elimination.* In the course of the evaluation it transpired that users were not only narrowing down the search by interrogating objects that might satisfy their information requirements but also by interrogating objects that

obviously did not satisfy those requirements. Searching proceeded by negation as much as confirmation, with users together working up agreement in the course of searching that certain groups of items were not appropriate. This suggested the implementation of functionality enabling users to remove objects from any current search, thus augmenting searching through a process of elimination.

The possibilities and constraints articulated by users in the course of using the environment to do their ordinary job of work elaborated requirements and future avenues of development that were subsequently implemented. Central to development were the mundane everyday troubles experienced in the course of getting the technology to work, which dominated users interaction with, and evaluation of, the prototype. Those troubles were entirely concerned with the *material affordances* the developed environment offered their everyday working practices: its ability provide efficacious views of objects in space; its ability to allow users to retrace their steps as and when required; the environment's ability to provide textual information; its ability to allow them to view related objects; its ability to allow them to actively rearrange the material arrangement of the space; and so on. The material demands of cooperative work in the real world while mundane are anything but trivial and need to be attended to and resolved if novel technologies are to be situated in actual circumstances of everyday use. Those needs are not well met by the current generation of VEs, which place a dominant emphasis on the internal character of cooperation.

5. Conclusion

We have presented the development of a real world application using a VE. In constructing a VE that has an ordinary everyday purpose, we have moved from the dominant conceptual vision of VEs that places emphasis on cooperation within the environment, to support cooperation in the real world. Attending to the mundane but nonetheless challenging material needs of a real community of praxis expands the research agenda for VE design and requires that we review the ways in which we think about the character of VEs. In particular, we would like to highlight a number of observations from our experiences of building a real world application to support cooperation in the real world.

- *Practice places constraints on design visions.* Design visions are often formulated by technical staff and for technical purposes. While there is nothing wrong with that, if novel technologies are to migrate into everyday life there is a need to be responsive to the mundane practicalities of particular work settings. Developing virtual technologies to support everyday uses points to the need to temper design visions with the mundane practicalities and material requirements of the work situations that the technology is to support.

- *The environment relies on an outside world.* In order to develop an environment of practical utility we have had to integrate 3D technology with existing online catalogues. The modest success of the developed environment relies on the fact that it connects to existing material resources that are used everyday. In the absence of such connections, it is difficult to see what utility the technology might offer. Identifying mundane resources and supporting their uses is integral

to the future development of VEs, then. Indeed, it is a matter of no small importance and challenge, particularly where it may entail integrating 3D with 2D representations (such as texts).

- *Avatars are not the primary locus of cooperation.* Perhaps the most important factor in the outside world is people. Prevalent VE concepts posit people proxies (avatars) within the VE but in our experience this is not necessary for cooperation, indeed to concentrate on avatars may be to ignore more important mediums of cooperation: namely, the material resources that cooperation relies upon. In library practice, cooperation takes place outside the virtual world as people work together in various constellations of assistance on shared views of the same screen. In important respects, this points to the more fundamental need to facilitate shared access to materials that may be worked upon as there is quite evidently a great deal more to cooperative work than face-to-face interaction.

These issues represent a movement away from some of the foundational visions of a VE. Nevertheless, motivated by conditions of actual use they are in line with some of the experiences of other researchers. For example, the need to link with external information is reflected in the advanced DEVA architecture and the need to more closely embrace the external world underpins work on techniques such as mixed reality boundaries (Koleva *et al.* 1999). Despite such developments there is still a predominant belief underpinning design that cooperation *should* take place within a virtual world that is somehow populated by users. By way of contrast, the developed environment adds value to cooperation not through immersing users in a virtual space but through using a VE to furnish previously unavailable material resources.

It is in light of this that we suggest the environment presented here is similar to the *Manufaktur* (Büscher *et al.* 1999) in that the "main focus is on richly representing the disposition of working materials rather than the disposition of people, in terms of avatars" (Büscher *et al.* 2000, p. 47). In contrast to many other VEs, the developed environment supports real world arrangements of cooperation, working materials, and working practices through the accomplishment of which searching gets done by users working together in various arrangements of shoulder-to-shoulder cooperation. Furthermore, the developed environment provides novel material resources which our evaluations suggest users wish to appropriate.

In conclusion, our experiences of situating a VE in the real world suggest that the marriage between the affordances of virtual technologies and the material requirements of real world working practices is an essential factor for consideration in ongoing research and the development of VEs. To promote that endeavour we have articulated one approach towards effecting that marriage; an approach that draws upon established research practices including ethnographic studies of work, cooperative prototyping, and situated evaluation. It is an approach that has, so far, been validated by the real experts in cooperative work: end-users practiced (in this case) in the ordinary, everyday art of accomplishing searching in the real world.

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