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ABSTRACT

Virtual Reality has attracted much attention in CSCW as a means for providing 'Collaborative Virtual Environments'. In this paper an alternative use is made of VR for CSCW. Our work focuses not upon VR as an actual interface to CSCW systems but as a means for providing a rich environment in which to, firstly, represent the results of ethnographic study and, secondly, to explore requirements for a collaborative system by envisioning new work arrangements. We report on our use of VR in this way and what it offers for supporting the transition between ethnographic fieldwork and system design. We also report on the transition from a 3D envisionment to designing a 2D system intended for real world use.

Keywords

Ethnography, Virtual Reality, Envisionment, VRML, Workspaces, Process simulation.

INTRODUCTION

In recent years a number of CSCW researchers have explored the use of emerging virtual reality (VR) technology as a means to support cooperative work [1, 10, 11]. The development of these 'Cooperative Virtual Environments' (CVEs) represents a radical shift away from single user VR systems. Such single user VR technologies are typically oriented towards supporting the manipulation of complex objects rendered in 3D, disembedded from any context and indeed often displayed floating in 'black space'. CVEs, on the other hand, are characterised by the rendering of virtual places (meeting rooms, theatres, marketplaces and so on) which are inhabited by multiple distributed users who are mutually represented to each other in order to support cooperative action and interaction within a shared virtual space. A number of CSCW applications of this technology have been reported such as virtual conferencing [10] and collaborative information retrieval [1]. Such 'mutual reality' applications attempt to utilise CVE technologies to provide arenas in which social interaction may take place and through which cooperative work may be supported.

For many in CSCW these virtual environments offer a new form of interface technology not only for interacting with computational resources such as database systems or Computer-Aided Design applications but for cooperating with other users [9]. The recent emergence of internet-based CVEs [8] and the development of standards such as VRML [18] has further heightened the interest in these technologies. The increased accessibility of such internet-based CVE technologies has significantly extended their user base and resulted in the rapid 'colonization' of large virtual spaces. That CVEs offer this potential for providing a new form of interface technology for CSCW has led some to explore the worth of social science contributions to the design and evaluation of such systems. Issues such as social interaction within CVEs have been studied [5, 6] while contributions from ethnography have included empirical studies of real world activities and settings in order to inform the design of CVE systems which may be inserted in support of the work in these settings [3] as well as scoping the applicability of CVE technology relative to the requirements of the work they seek to support [12]. This paper, however, provides a different use of virtual reality technology for CSCW. It focuses not upon the technology as an actual interface to a system, but upon the potential for using virtual environments as a means of exploring and articulating requirements for collaborative systems. Our emphasis has not been upon making VR into a CSCW environment through developing CVE functionalities, but upon the use of VR as a tool for addressing a number of specific problematics within CSCW concerning social science contributions to system design. In this way, the paper offers an alternative relation between ethnography and VR technology in CSCW. This is achieved through the development of VR models which are grounded in empirical studies of real world settings and are oriented towards CSCW design but which are nevertheless not CVEs nor themselves intended as interfaces through which cooperative work will be conducted.

The Cross-over Between 2D and 3D

Before describing our work in detail it is worth noting a further difference between this work and previous research in CSCW. The development of CVEs has been informed by a background of concepts identified over the years through the experience of attempting to produce effective 2D CSCW systems. Well established notions in CSCW such as ‘awareness’ and ‘shared context’ helped scope the rationale for much of the first CVE work. More recently a number of researchers have derived insights through explicitly considering this cross-over between 2D and 3D collaborative environments. Smith [16], for example, has transferred concepts developed in the course of designing 2D multi-user interfaces to 3D CVEs. In particular, he extends the provision of ‘subjective views’ for different participants to CVEs. Rodden [13], on the other hand, has explored the applicability of representations such as graph theory for describing both 2D and 3D cooperative systems. Additionally, Benford et al’s [2] staging of artistic events using 3D CVE technology has suggested orientations to such occasions and their ‘event management’ which may be equally applicable to some 2D multi-user sessions. The research reported here also addresses the transitions between 2D and 3D collaborative environments, though in different ways to those described above. This previous work has considered *general* concepts developed in one technology for their applicability in another technology. Existing concepts from 2D CSCW systems have been applied to 3D CVEs and issues discovered through the development of rich 3D worlds have been transferred to 2D cooperative systems. Our work has, however, involved the use of VR in the articulation of requirements for a *specific* cooperative system and the transfer of particular features of a design *solution* from a 3D envisionment to a 2D platform. This use of VR has taken place within the context of a larger project aiming to develop specific system solutions for use in the near term as commercial products for particular work settings.

AN ETHNOGRAPHY OF LARGE-SCALE DOCUMENT PRODUCTION

The background to this research has been work carried out within the Studies of Technology, Organisations and Work group (STOW) in the Cambridge Laboratory of the Xerox Research Centre Europe (XRCE). A major focus for the group is to understand the impacts which network technologies have upon the ways in which organisations do business and coordinate activities. Work place studies are used to investigate the impacts of network technologies upon work practices and work processes and to understand, for a specific work setting, what opportunities are enabled by these technologies and what barriers exist to their effective use.

One such study within STOW has investigated large-scale document production through observations of the ways in which factory production printing is managed and organised [7, 4]. The organisation studied — Establishment Printers (EP) — has multiple print sites geographically dispersed throughout the UK. Typically each site may manage on any one day the production of over a million documents. One of the topics of this study has been an attempt to understand the impacts of networking together these sites so as to allow distributed document production (DDP) across sites. The focus has been upon understanding the work practice and business issues involved in DDP rather than technical issues of bandwidth, file format compatibility and the like. The study has been able to identify some of the enablers and barriers to DDP that exist. Networking for DDP offers clear advantages in terms of providing the capability for load balancing across sites, for making available specialist resources previously only accessible at one site to the whole organisation, for allowing production at the site nearest the customer or the customer's customer and so on. A distributed production environment would mean though that certain problematics would be systematically encountered and, unless addressed, these could constitute serious barriers to making DDP work in practice. For example, effective load balancing requires knowledge of the production capacity utilization across sites. There is little point distributing a print job to another site for production if that site lacks the capacity (of the right sort at the right time) for producing the job. However, at present the only mechanism for obtaining this information about spare capacity, and hence the only means to identify which sites to collaborate with in distributed production, is to telephone around all of the sites. This is a ‘hit and miss’ process that would be unable to cope with the demands of regularly engaging in DDP.

Moving Towards Design

This ethnography of large-scale document production had produced a detailed understanding of factory production printing and had isolated some of the central issues that would effect a move towards networking production environments. The challenge for STOW was to move from this ethnographic fieldwork towards informing system design through a process of conveying what had been observed at EP sites about how work was done there and by presenting supporting fieldwork materials (photographs, videos and so on) in a manner which could inform the design of systems to support DDP. In addressing this challenge we faced a number of problems, problems which have occupied many in CSCW for some time. That is, having spent long periods of time at a work place attempting to understand in detail how work there is undertaken there, nevertheless, remains a need to, firstly, effectively convey the rich details of what is observed at a work site to those who are not able themselves to visit the site and, secondly, to represent the mass of materials which are collected during fieldwork in a form which is most useful for design purposes.

Within CSCW such concerns have motivated the development of tools which are not so much aimed at supporting the traditional activities of the ethnographer in structuring and organising fieldwork data for analysis purposes, but which are aimed at assisting in the *presentation* of ethnographic accounts for the specific purposes of informing system design. Hence, in addition to existing qualitative data analysis applications such as Nudist [14] and The Ethnograph [15], which support tasks such as data coding and indexing, ethnographers in CSCW have explored the use of new tools such as the Designers' Note Pad (DNP) [17] in an attempt to also make the results of their analyses more readily available in forms which may be more suitable for system design purposes. By supporting diagrammatic representations, tools such as DNP attempt to allow the presentation of ethnographic accounts in forms other than traditional natural language and relatively unstructured text. However, a third challenge faced our project as it sought to move from ethnographic fieldwork to systems design. This concerned a desire not only to provide intelligence on the work practices within a print production environment but also to convey ideas which had emerged from the project for orders of solution to the problems of DDP based upon a need to overcome anticipated barriers to DDP. That is, our intention was not to only provide accounts of work as it is presently undertaken nor to only provide critiques of existing systems such as that reported in [4] (interesting though they may be), but to begin a constructive engagement with system design. We required a means for moving from detailed observations of present work practices to the development of requirements for future technologies and orders of design solutions to existing or foreseeable problems for the work. Again, in having to address this topic, we orient towards a persistent issue for ethnographic work within CSCW. That is, according to some, ethnography suffers from being overly focused upon present work practices which is problematic given that new systems are inevitably transforming of the ways in which work is done. While we do not necessarily agree with the formulation of this criticism, our work on this project has involved finding a way to develop and articulate requirements for future DDP systems on the basis of fieldwork.

Articulating a 'Lightweight' Solution

In particular we sought a way to convey an alternative order of solution to the problems of DDP to that which was commonly assumed to be the best way forward within the industry and indeed within parts of our own organisation. We wanted to suggest that a 'lightweight' solution to supporting collaboration between sites was possible. Our ideas for a lightweight solution were 'multi-dimensional' and there were a number of different elements that we needed to convey.

Firstly, such a solution had an *organisational* element to it in that it aimed to preserve the present status of EP sites which operate as independent business units with their own customers, targets, accounts, charging and so forth. This autonomy of the sites provided them with the essential ability to compete in local markets with locally determined prices and locally based customers. In addition, it also allowed local control over the ordering of production as described in [7] which, given the massively contingent nature of their work, was vital for effective production management. Our ideas for a 'lightweight' solution for DDP sought to avoid the need for organisational restructuring and to avoid the formation of some centralised 'command and control' unit to automatically dispatch jobs to what would then become satellite units.

Additionally, our notion of a 'lightweight' solution had *work practice* and *work process* elements to it in that we wished to extend rather than replace existing ways of working. These existing practices were not only successful but, given that DDP was likely to add to rather than replace existing single site production, such practices would remain necessary even in a fully networked environment. In other words, print work that arose from jobs received over a DDP network would have to be smoothly interwoven with locally sourced jobs being managed through the established work practices in these sites. We sought, then, a DDP system that left these practices intact and enabled new procedures for DDP to be folded into existing ways of working.

Finally, we also sought to build upon the *artefacts* and *devices* that were presently used to coordinate and manage production within single sites by making these artefacts available in a distributed networked environment. These devices included the production schedules (or 'Forward Loading Boards') and production monitoring devices (or 'Load Monitors') described in [7]. Our focus at this stage was not so much on the improvement of these devices with the addition of extra features and functionality (though this was clearly possible and desirable); instead we were concerned initially to see these artefacts as evolved and locally constructed solutions to making manageable the 'calculus of production' [7] in a print site. Our 'lightweight' approach sought to comprehend the *order* of solution that these devices presented. For example, it sought to understand how they displayed 'at a glance' the status of production, how they were instantly revisable in the light of unfolding circumstances, how they formed the focus for collaborative decision making in production management, how they enabled managers to keep the order of work 'in their heads' and so forth. Our 'lightweight' solution attempted to draw upon the nature of these devices but to extend their usefulness to address the barriers that would arise from networking for distributed production. In seeking to show how they could be made available within a networked environment in ways which would address these barriers we also sought to articulate a 'lightweight' solution which allowed the use of existing practices and stock-in-trade competencies in the interpretation of these artefacts. In other words, our intention was that the skills used in interpreting these artefacts as they presently existed within single sites could, in a DDP scenario, be deployed in interpreting similar artefacts made available by other sites through a networked production management system.

(In fact our notion of a 'lightweight' solution also had *technological* elements to it in terms of avoiding the need for a homogeneous technological infrastructure and so as to allow more flexible collaborations between 'loosely coupled' sites. However, as these issues mainly concern the development of an actual system for DDP rather than the VR envisionment described in this paper, then they are not elaborated upon here).

The challenge for us, however, was to find a way to give some form to our alternative order of solution and, in so doing, to unpack some of its details.

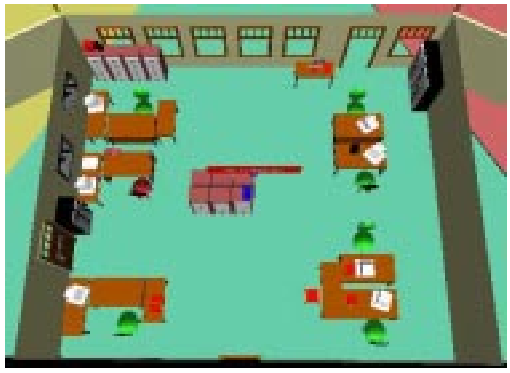
MODELING WORK PLACES

In this context of seeking to move from ethnographic fieldwork to system design, we have turned to using VR not as an actual interface to support the work observed but as a mode of representation for fieldwork *and* as a means for visualising future ways of working. We draw upon the powerful modeling capabilities of VR in order to develop models of real world work environments and to build on these to produce visualisations of future workspaces which are nevertheless firmly grounded in a detailed understanding of specific ways of working. For us this is the key to using VR to articulate system requirements on the basis of work place studies. In this way, the models which we build are not rapid prototypes of early versions of an actual system interface, but rather provide an environment which visualises an order of solution to work problems. Furthermore, it was necessary for us to convey elements of the 'lightweight' solution which were not only technological but involved new work processes, work practices and particular organisational operational structures. These elements can be at best implicit when the level of a specific user interface design has been reached and we were concerned to use an envisionment environment in which they too could remain visible. Finally, much of what we wanted to convey concerned the temporal and spatial nature of existing and future work processes and, as we shall describe, 3D VR offered a less static medium than floor plans, photographs or process models in this regard.

VIRTUAL WORKSPACES FOR DISTRIBUTED DOCUMENT PRODUCTION

We have then developed comprehensive VR models of EP print factories in order to articulate and provide access to our fieldwork materials as well as to provide an environment in which future scenarios for DDP can be visualised (for example, Figures 1, 2 and 3). We have used the VRML language in order to make our models navigable through a web browser and hence readily accessible to our globally distributed system design teams. The models we have built convey a range of features of the work settings and contain a number of components worth describing.

Figures 1, 2 and 3: Models of EP print factories



Conveying Spatial Layout

Firstly, we have built models of all the departments (Administration, Origination, Digital Print and so forth) within EP sites. These are the locations where all of the various print production processes take place (order entry, scheduling, proofing, plate making and so on). The 3D models allow a viewer to gain a sense of the layout of EP sites, their departments, work areas, machines, desks, artefacts and the like. Conveying spatial layout in this way is oriented towards presenting aspects of the work arrangements that are socially significant and significant for the work rather than purely presenting an architectural model. For while architects do use 3D models precisely because 2D floor plans can be notoriously hard to interpret when seeking to gain a sense of a site, our concerns extend to include the role of spatial arrangements in the organisation of work. For example, it is possible to see in these models how the production schedule in EP does not reside on someone's computer screen but is a public display in the work place and is visible 'at a glance' from the desks within the Administration Department which are themselves allocated to particular role incumbents. In this way, VR has proved to be a useful medium for displaying how the everyday activities of 'looking and seeing' and the practices of 'using your eyes' are supported by the arrangements of the work environment. (As we shall discuss, this has been important for us when seeking to show how these practices, which are presently restricted to a local site, might be extended to a distributed environment through technology and hence form the basis of a lightweight solution to some of the potential problems of DDP).

Animations of Work Process

Secondly, in addition to the free navigation of these models, an animated simulation of the work processes that a print job goes through has been built. This shows the movement of artefacts through the work place, the transformation of artefacts and the operations of associated machines upon those artefacts. The simulation utilizes the functionality of VRML 2.0 to provide a dynamic component to the model of the work site (something that we have noted is missing in other representations such as floor plans or static process diagrams utilized in tools such as DNP). The simulation is under the user's control and is stepped through by clicking arrow objects placed at points within the model. These arrows trigger the stages in the process simulation. They also change the user's viewpoint onto the world so that their view moves from, for example, one desk to another while the movements of the objects of the work at that point (typically documents) are animated (Figure 4). In this way, they allow a user to 'follow the job' as it moves through production in the print factory. The workflow is visualised and contextualised within the spatial layout of the workplace. Transformations of the physical materials of a print job are also animated. For example, the models visualize the placement of metal printing plates on to EP's large traditional print presses and show the subsequent production of printed paper coming off the presses.

Simulations of Coordination Devices

Thirdly, specific production management artefacts (such as 'Forward Loading Board' schedules and 'Load Monitors' [7]) have also been built in a form which end-users can directly manipulate and consequently use to simulate operations of the corresponding real world artefacts.

In the screen shot shown in Figure 5, we see the Administration Manager's desk during the order entry process. Data is entered from the 'Customer Order Form' into a database through the manager's PC. From this a 'Job Ticket' is printed off. Above the manager's desk is the 'Forward Loading Board' which displays the production

Figure 4: Snapshots of an animated work process

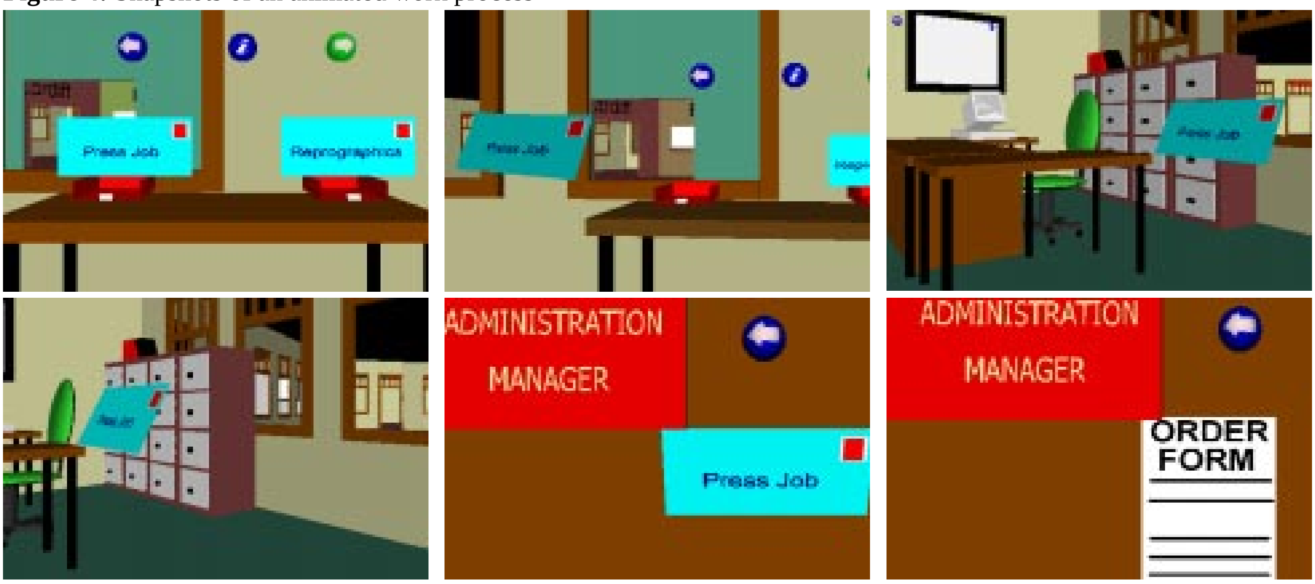


Figure 5: The Administration Manager's desk

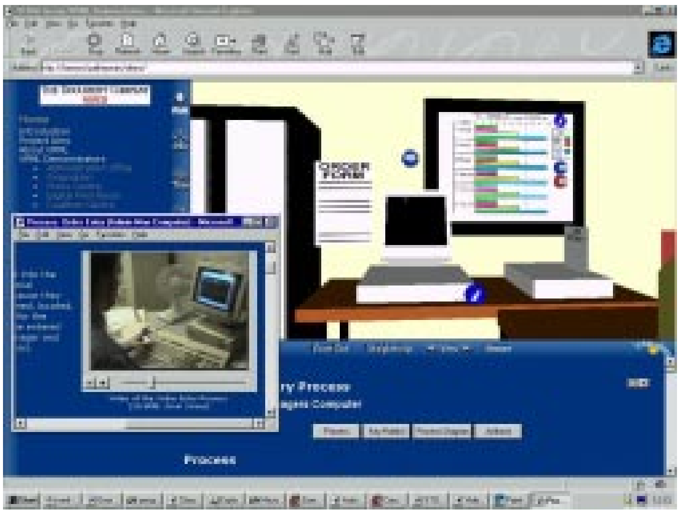
schedule. The order entry process is animated within this VRML model and the 'Forward Loading Board' is directly manipulable in ways in which the real world artefact is (for example, by placing the cursor over the device and dragging one of the columns to 'block out' allocated capacity on a printing press). This VRML model is presented within one frame of a web browser. The frame underneath the model is used to present descriptions and information derived from fieldwork and which are relevant to the process stage being viewed at the time.

Providing Detail on Demand

Fourthly, further 'information nodes' are included within the models using an '*i*' icon. These provide 'detail on demand' by allowing users to access (if they wish) additional multi-media presentations of fieldwork materials which have been segmented into information on roles, artefacts, places and processes and which are relevant to the point where these information nodes are placed. These provide not only access to additional descriptive information, but also to further results of the analysis work of the project concerning the work practices of large-scale document production. In the screen shot shown in Figure 6, an information node has brought up a video of the real world activities involved in order entry. Process diagrams, photographs, scanned documents and the like can also be accessed in this way. (Additionally, this information can be directly accessed at any point through menus that are permanently displayed in the left-hand frame of the browser).

The VRML model acts, then, as a persistent top level representation from which further information and representations can be accessed as required or according to the context provided by the 3D model. This allows us to utilize the strengths of the VR representation (spatial context, free navigation and so on) while also linking to other representations such as process diagrams or video clips which may better convey certain forms of information such as process overviews or fine details of work activities. The model may then augment rather than replace text based accounts, process models and so forth.

Figure 6: Information node for the Order Entry process



VISUALISING FUTURE WAYS OF WORKING

As well as providing an innovative way of presenting fieldwork materials derived from workplace studies, VRML offers a rich modeling environment in which new collaborative work arrangements can be envisioned. In this way it was possible for us to begin to move beyond representations of how things are now to how they may be. For example, in the case of DDP there is a transition from locally based single site document production to multi-site distributed production through the use of network technologies.

Conceiving of Future Spaces

In order to begin to give some form to our alternative ‘lightweight’ approach to DDP, we developed a model of a virtual centre that was accessible from all the distributed sites we had modeled. This gave us a starting point for considering how an electronically generated centre could support DDP collaborations without requiring an organization to restructure to provide a physical centre. From this starting point it has been possible to articulate further DDP requirements by addressing questions such as ‘what would this space be used for?’, ‘why is it needed?’, ‘who would go there and when?’ and ‘where would they go when leaving the space?’.

Populating Spaces with Artefacts

It has also been possible using this model to show how a ‘lightweight’ order of solution to DDP barriers could build upon the existing production management devices in use in EP sites. By addressing the questions of ‘what would need to be in this space to enable DDP?’ and ‘what artefacts would people take with them to conduct DDP?’ in terms of the possible uses of existing devices, then we have been able to further articulate our ‘lightweight’ alternative solution.

Consequently, in the screen shot shown in Figure 7, we see a virtual ‘coalition centre’ model which acts as a ‘hub’ which can be visited from multiple EP sites. This virtual centre acts as a meeting place for autonomous sites, not a command and control centre. Within the centre are displays of the different sites’ production management devices, the relevance of which has been determined by the fieldwork analysis. For example, multiple Forward Loading Boards from different sites are displayed within the centre. As each of these represent the planned production capacity utilization of a site, then the visual juxtaposition of the collection of such devices within the same electronically generated space may enable human schedulers to use their existing skills in ‘looking and seeing’ to identify ‘at a glance’ spare capacity across sites rather than just within a single site. In this way, we are able to envision elements of a ‘lightweight’ solution to one of the identified barriers to effective load balancing in DDP. Such an order of solution relies upon the visual display of existing production management artefacts and hence contrasts with alternative ‘heavyweight’ systems that either require the technical integration and exchange of data between distributed scheduling engines for the purposes of automating job allocations or the centralisation of production control into the hands of some ‘command’ centre. Furthermore, such a persistent graphical display offers advantages over the temporary audio connections available at present through telephoning around sites.

Mapping Future Processes

Additionally, because this new virtual place can be modeled along side the facsimile models of real world places (Administration, Origination, Digital Print and so on) in *continuous* space, then it is possible to show in the model movements in and out of these places and the transportation of artefacts across the organizational boundaries which are visualized in the models.

Figure 7: The Coalition Centre

New work processes required in a future DDP scenario can be modeled and can include those which cross traditional site boundaries and which in our 'lightweight' solution utilize an electronically generated 'coalition centre'. For example, previous screen shots showed models in which the Forward Loading Board is visualized on display in the Administration department of a site (Figures 5 and 6). Attached to this artefact in the model are two arrow nodes, one of which triggers a simulation of present work processes for single site production while the second triggers a step through of possible future work processes needed for DDP. These two routes are then visualized in the same environment and the simulation of future work processes is able to convey the need to transport particular artefacts and materials from one site to another. Locating these two arrows on the Forward Loading Board is also used to indicate one of the results of the project's analysis — that it is at scheduling time that a decision can be made between local or remote DDP production and that it is at this point that new work processes for DDP will have to be folded into existing ways of working.

DISCUSSION

Within CSCW, ethnography has been pioneered as a method which seems to hold potential for informing system design. To realise this potential it is essential that means for bridging between fieldwork and design be found. It has, however, long been recognized that moving from one to the other is not necessarily an easy matter. This work seeks to add to the toolkit of methods available to support this transition by providing a novel presentation of fieldwork materials. The presentation we have developed *augments* traditionally text based fieldwork accounts with other media and segments accounts by separating some of the threads which may be interwoven in conventional descriptions as well as using hypermedia to change the linearity and accessibility of these accounts. VRML is used to provide a persistent top-level *orienting* representation from which further purpose specific representations, such as process diagrams, can be accessed on demand. In addition, VR provides a rich environment for articulating requirements for orders of solution to work problems and for conveying a range of spatial and temporal dimensions of present and future work arrangements. To conclude, we wish to briefly reflect upon the experiences of using this tool in moving from our fieldwork to system design and outline some of the further directions we are pursuing.

'Gearing into' Design

It has been our experience that using VR in this way has facilitated the rapid and effective leveraging of a fieldworker's knowledge of a work environment in deriving potential contributions for system design. Using VR as a mode of representation meant that we were able to move quickly from debriefing sessions with an ethnographer to iteratively building up facsimile models of the workplaces that were so familiar to the fieldworker as a result of their studies. This account of the workplace could be developed using 'primitives' which the fieldworker could instantly relate to. The fieldworker could easily 'gear into' the development of a model being produced in terms of graphical representations of existing spaces, artefacts and devices — rooms, desks, Forward Loading Boards and so forth. Once the geometry of the spaces was in place, the models could then be augmented with spatial and temporal information on the movements, transitions and transformations that result from the activities of the work. (However, while such models have many useful features that provide us with powerful resources for conveying fieldwork materials and design concepts, it is clearly the case that additional effort is required to construct such virtual reality models. Currently, in order to build the type of 3D VR model that we have portrayed in this paper, it is necessary to have an in-depth understanding of VR toolkits. The problem is not one of simply constructing a geometric model to represent a building, but that in order to 'bring the model to life', the developer must construct a complex network of interlinked behaviours. Exactly how much effort is involved, however, is dependent upon just what tools are available. It is already possible, for example, to download libraries of common geometric objects (desks, chairs and the like) from the internet and in creating the models presented here we also generated a small library of useful behaviour objects, enabling more rapid future development through the re-use of existing components. More sophisticated and higher-level creation tools such as 'key frame editors' are also becoming available all the time. Consequently, it is already the case that building the models presented here would be a very different order of endeavor today to what it was when we were engaged in developing them).

It is important to stress, though, that the models we have developed are *analytic* models. We mean by this that they embody an analysis of the setting and the organisation of the work encountered in it. Thus, the models are not the presentation of 'raw data' but rather what has been made of such data by the ethnographer. What is modeled in the VR environment is, consequently, not simply domain knowledge or surface characteristics of the setting. (In fact, VRML is in many ways particularly poor for conveying surface detail with any degree of photorealism). In part the effort involved in developing complex VRML models such as ours from the ground up, object-by-object, surface-by-surface using the simple geometric primitives of VRML forced us to give careful consideration to just what it was that was important to convey and present.

In this sense the represented world of a virtual model may perhaps offer certain advantages over photographic or video records of the work environment when what one is concerned with is conveying an account of particular features of the work for system designers. The reason for this is that merely presenting a setting in visual form using, for example, video recordings will still require the designer to attempt to formulate an understanding of the setting and the organisation of the work they are designing for but without equipping them with the situated and contextual resources with which to understand and find that organisation in what they see. The designer would have little more than a partial view of the situation and gain little more than a 'tourist' perspective upon the scenes of a print site. On the other hand, the traditional purely text based ways of presenting an analysis of the setting and the organisation of the work, although indeed presenting the results of an ethnographic study, are often unable to present much of the data the analysis is based upon and do not provide the means with which to make the analysis more flexible. The VR model then has the advantage of presenting an analysis of the setting and the work based upon ethnographic research while also providing some of the data and a flexible method of organising it. In this way it does not completely tie the designer to what the ethnographer wishes to convey.

Additionally, the model provides the opportunity to understand different configurations of working and organising processes, neither of which is available through traditional forms of representing ethnography in design. The ability to construct hypothetical new functionalities in the form of, for example, new spaces for interaction and cooperative work also, in this case at least, facilitated the process of idea generation and stimulated ethnographers and designers in working together to imagine new possibilities. Utilizing such rich VR environments can 'kick start' the design process by allowing all participants to 'gear into' designing envisionments which start from the familiar and extend to the novel. It provided a context within which to address the requirements for distributing information between sites by addressing the issues in terms of questions about what would be in these spaces, what would be transported across existing organisational boundaries and so on. Furthermore, as we always viewed the VR environment very much as an envisionment and not a system for deployment in support of the actual conduct of the work, then it had the additional benefit of encouraging us not to narrow down too much too soon the design possibilities being explored.

Collaborative Virtual Envisionments

In considering the future directions that this work may take, we are considering revisiting some of the multi-user capabilities offered by CVE technology. For though we only set out to provide a means through which requirements for a cooperative system could be articulated using VR, the development of these virtual models does present further interesting possibilities for developing a CVE version. Producing a multi-user version of the model could enable the telepresentation of the fieldwork and the envisionment of orders of solution for DDP. Remote designers and ethnographers may be able to cooperatively explore the models, simulating roles and interactions if they wish. The ability to 'inhabit' a role could, for example, be particularly useful when it is important to not only be able to follow a job through a work environment but to be able to take the perspective of a role within a workflow. We are already exploiting the abilities for remote viewing of the VRML models through standard web browsers in our distributed development efforts and are looking to explore a CVE version of the models in the future.

Migrating Understandings to 2D Platforms

Effectively conveying an alternative lightweight solution has enabled us to inform high-level product visions and market strategies. However, our final challenge has been to also migrate the understandings developed using this modeling environment to the design of less 'exotic' technologies which are more likely to be deployed in the near term as means for actually supporting DDP. Our concern has been to facilitate the migration of specific features of the envisionment from 3D to 2D system design. This work is already well underway, and the VR models we have developed have enabled those designers with whom we are working most closely on developing prototypes and who have never visited the field sites to gain a sense of the fieldwork environment, to rapidly understand the order of solutions we envisage and to see the grounding and sense of these solutions within the work of factory production printing. Such results might have been achieved through other means, such as handing over fieldwork reports, but our ability to augment such representations with a rich 3D environment provides us with a range of extra resources for conveying field work and design concepts. For example, within one environment we can present the spatial and temporal dimensions of work such that workflows are visualised within the context of a 3D navigable model of the work setting, we can construct new workspaces as extensions to models of existing real world places, we can model possible work processes in and through these various spaces and so forth.

Our approach in developing a 2D prototype has been to exploit the fact that a number of CSCW technologies, which, while not VR based, nevertheless, create shared workspaces. We are using 2D shared and persistent workspace technologies to develop electronically generated 'coalition centres' and other spaces designed to support DDP 'in anger'. Having articulated design requirements initially in this rich VRML environment (and in terms of modeling places, the movements of artefacts, boundaries and so on rather than user interface issues of menus, buttons and the like) it is proving possible to develop corollaries of these VRML models on other platforms as prototypes of potential actual systems. We have been able, for example, to reproduce in 2D the means to identify spare capacity across a coalition of sites through the visual juxtaposition of existing production management artefacts made available in a shared space provided by a networked environment. That is not to say, however, that the development of the actual system with which we are presently engaged does not itself involve a whole range of further decisions, further refinements of requirements, further reflections upon the fieldwork and so on. Similarly it is not the case that our analytic VR model then simply becomes a design model for many of the elements of the VR envisionment convey aspects of the multi-dimensional lightweight solution which are not and need not be translated into user interface buttons, menus and the like. For example, the new work flows and their points of intersection with existing work processes are explicitly visualised in the VR envisionment but need not then be built as widgets in a user interface though the interface provides features to support those processes. It is the case, though, that our progress in developing this 2D system owes a great deal of direction and form to the VR envisionment described in this paper and is oriented towards providing fundamentally the same order of solution as that envisioned through the use of VR.

This work has taken place within the context of a group examining the impacts of network technologies upon work and has concerned the networking of geographically distributed sites for the purposes of distributed document production. Our needs were, for example, to convey spatial and temporal dimensions of organisational and inter-organisational processes, to convey a multi-dimensional solution involving organisational, work process, work practice and coordination device elements and to further the aims of the larger project to develop commercial products for a particular work setting. In this context, VR gave us resources to convey what we needed to convey. We hope that in the context of different studies and different projects others find VR similarly useful as a means to represent fieldwork and articulate design requirements.

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