

Information-based Model for Knowledge Management

By Duska Rosenberg¹ & Keith Devlin²

Abstract

In this paper recent research is presented, focused on the development and application of an information-based model that aims to capture formally the explicit and implicit aspects of knowledge. The model is informed by the empirical study of real-life interaction. We use discourse analysis in order to bring to light social and organizational constraints that shape shared knowledge. Both the constraints and the processes that regulate knowledge sharing are further analyzed using Situation Theory, a mathematical theory of information. The resulting conceptual framework is multi-disciplinary and should be regarded as a bridge between two distinct types of analytical approach; the empirical data-oriented that captures the full complexity of knowledge phenomena and the more structured approach that guides the creation and implementation of models of knowledge relevant to technology design.

The information-based model is further illustrated with three examples. The first introduces the information stance in the analysis of social knowledge that is shared by members of our culture. The second illustrates the relevance of the information stance in analyzing a shared artifact – a form that is a part of organizational memory in a large manufacturing firm. The third is focused on analyzing the role of multimedia communications as a resource for knowledge management within and between distributed organizations.

A particular application of multimedia, an experimental prototype called People and Information Finder (PIF) has been developed to study novel patterns of knowledge management in a technology-enhanced workplace³. The PIF prototype has provided a valuable elicitation tool that helped to discover how people learn about one another and to explicate what social knowledge they bring into a collaborative setting. Discovery methods and elicitation techniques used in this context are based on studies of human communication, but are focused on the relative importance of different information media such as text, abstractions (schemas, diagrams), dynamic visualizations and video recordings provided in PIF.

The strengths and weaknesses of the information stance, as well as the resulting conceptual framework, are also discussed, specifically in the context of the PIF example.

Keywords:

Discovery methods, Elicitation, Ethnography of Communication, Information, Organizational Learning, Shared Knowledge, Situation Theory.

¹ School of Management, Royal Holloway University of London and Senior Researcher CSLI Stanford University

² Department of Mathematics and Senior Researcher CSLI, Stanford University

³ The work on the role of PIF in knowledge management is dedicated to the memory of Nicholas Farrow, the manager of the PIF design and implementation which was part of the EU-funded CICC project (Collaborative Integrated Communications for Construction) who died suddenly in 1999.

1. Introduction

Polany's (1958) distinction between tacit and objective knowledge provides the fundamental insights into the phenomena associated with knowledge and information. Tacit knowledge is gained through personal experience and cannot be shared or formalized. It has to be articulated before it becomes "objective" knowledge, but, as Polanyi points out, even the scientific knowledge, as an example of "objective" knowledge is embedded in its social, cultural and historic context.

The processes of articulation make it possible for tacit knowledge to be described and shared so that they can underpin interaction between individuals and organizations with the environment. An account of tacit knowledge needs to take into account the role of organizational members, tools, tasks, and their sub-networks (Argote & Ingram 2000), as much knowledge in organizations is tacit or hard to articulate (Nonaka & Takeuchi 1995). Boisot (1997) in his definition of Knowledge Assets focuses on the structures that enable knowledge and information flows in order to provide theoretically sound and practically relevant accounts of knowledge phenomena. In particular, he focuses on knowledge assets of the modern organization and on the higher level learning processes that make it possible for us to inform the design of technology-enhanced organizational memories.

The research questions to be addressed here, concern the nature of the processes of articulation, the interplay between external and internal factors (the context) that influence these processes and the resources required for articulation to be accomplished. This – knowledge and information based orientation – has provided the philosophical basis for the development of a variety of analytical frameworks, methods and techniques. They span a multi-disciplinary community of researchers, including people-oriented organization and communication studies, technology-oriented information systems studies, and those in-between such as CSCW (computer-supported collaborative work), HCI (human-computer interaction) and more recently CMC (computer-mediated communication). Last, but not least, cognitive science and the discipline of artificial intelligence have from the very beginning been engaged in the creation of computational models of human knowledge and understanding.

This paper builds on the multi-disciplinary research that aims to bridge the gap between distinct intellectual traditions which underpin social science studies on the one hand, and cognitive science studies on the other. Our starting point is the view that the main objectives of the former are to account for human phenomena empirically, by capturing their full complexity in context, while the latter are focused on developing formal and computational models to gain deeper insight into particular aspects of such phenomena.

The focus on knowledge management makes it possible for us to side-step the recognized conflict between the two traditions. We attempt to develop a unified conceptual framework that utilizes empirical insights to identify the aspects of implicit knowledge that are relevant to knowledge management. We then focus on the more structured analysis using the tools of Situation Theory; a mathematical theory of information. The expected result is a unified framework for the analysis of knowledge phenomena that is inspired by empirical insights, but achieves a level of granularity more appropriate to the requirements of those who design and implement knowledge technologies than that provided by empirical studies alone.

In this context we carried out discourse analysis of real-life interaction and knowledge sharing in a distributed organization. This has resulted in an understanding of articulation and negotiation processes that underpin real-life knowledge management and the use of organizational memories. Situation Theory has then provided an information-based conceptual framework that brings structure and precision to some aspects of the empirical results.

The discussion in this paper will be focused on the features of the information-based framework that make it particularly suitable for identifying the key issues in knowledge management that arise from patterns of use of organizational memories in real-life. More generally, we explore the way information-based way of thinking about (and analyzing) co-action⁴ may throw light on the processes that utilize tacit knowledge. We adopt the 'information stance' (following Dennet (1989) concept of the 'intentional stance'), that is, we talk as if information really exists and approach co-action in terms of the creation, acquisition, storage, transmission, exchange, sharing and utilization of information.

2. The Information-based Model for Knowledge Management

As a starting point, we take the concept of information in its everyday use and make it more precise by way of mathematical definition. We use that additional precision to examine in some detail the distinction between explicit and tacit knowledge of an organization. More specifically we focus on a distributed organization where information and knowledge flows are mediated by technology and examine the impacts of mediation on the sharing of tacit knowledge.

In the context of organization studies and information systems design the concepts of information and knowledge management have been related to the view of information and knowledge as a commodity that is largely independent of the way it is embodied in a representation. Knowledge can be bought, stolen, exchanged and transmitted across channels often created by technology. It can also be processed, using information and knowledge technologies. It can be stored in an object or an artifact, such as a book, a database or any physical object that can be said to contain knowledge about a topic, or events, or people.

Later in this paper, we discuss in more detail, how a manufacturing organization uses a document about the repairs of computer equipment to share knowledge not only of the actual repairs, but also to improve its knowledge of its own practices and processes, in other words to improve organizational learning. Thus knowledge management in organizational practice suggests that the view of knowledge as a commodity may not be sufficient to capture all the relevant aspects of knowledge management. It may be directly relevant to the design and implementation of data structures, knowledge bases and others, but will not capture the more dynamic aspects of knowledge as it is created and shared in social interaction. Since much of this knowledge is implicit, novel methods are needed to both empirically understand its significance in real-life and to formally define the structures and processes that may improve the design of knowledge technologies to support it.

To illustrate this point, we take as an example a classic analysis by G Sacks (1972) of two sentences that form the beginning of a story: "The baby cried. The mother picked it up."

⁴ cooperative, coordinated, communicative action between two or more people

Sacks asks two key questions about our ability to understand these sentences, namely why is it that everybody assumes that the mother is the baby's mother and that the mother picked it up because it cried? Moreover, we may form this interpretation without knowing who the mother is, or who the baby is.

There is nothing in the context that can explicitly guide our interpretation of the relationship between the baby and the mother, nor of the meaning of their actions. According to Sacks, this example shows '... the fine power of a culture. It does not, so to speak, merely fill brains in roughly the same way; it fills them so that they are alike in fine detail....' (op.cit. p 327). Sacks analyzes this story to make explicit the social relationships that are not overtly expressed. He shows how they draw upon their knowledge of the social systems in order to arrive at such interpretations. His main concern is to explain how shared social knowledge makes their actions mutually intelligible and interpretable.

In our, information-based, approach we identify the informational and cognitive structures that allow tacit knowledge to be articulated and thus lead to the shared knowledge of the situation described in the story. Our focus is on interaction, as we track the way people cooperate in order for their co-action to be successful. By carrying out our analysis in terms of information flow inspired by the framework of situation theory, we seek to highlight how information-based approach can lead to the development of relational structures where relations that apply in a given situation represent the regularities that people are aware of. In other words, we assume that tacit knowledge can be defined as regularities and the relations that guide co-action but are not in fact explicitly stated.

One of the advantages of the framework and notation provided by Situation Theory is that it allows us to express partial information about complex relations. For example, the relation *eat* presupposes agent, object, instrument, place, time, but much of this information can remain implicit, as in "I'm eating." This makes it possible to choose which aspect of the structure to emphasize in a given instance of interaction. And this choice of emphasis also carries information in its own right, since it is recognized and interpreted as attitude or intent.

In Situation Theory recognition is made of the partiality of information due to the finite, *situated*, nature of the agent (human, animal or machine) with limited cognitive resources. Any agent must employ necessarily limited information extracted from the environment in order to reason and communicate effectively. The basic ontology of situation theory consists of entities that a finite, cognitive agent individuates and/or discriminates as it makes its way in the world: spatial and temporal locations, individuals, relations, situations, types, parameters and a number of higher-order entities. The objects (known as uniformities) in this ontology represent the intuition that in a study of co-action (both physical and cognitive) of a particular agent or species of agent, we notice that there are certain regularities or uniformities that the agent either individuates or else discriminates in its behaviour. The ontology of situation theory also allows for the fact that different people may discriminate differently⁵.

This is true not only of individuals but also of groups, teams, communities. If A and B are engaged in a dialogue or a conversation, or indeed any other form of joint action, they recognize uniformities as individuals in similar ways. Socially they negotiate the precise meanings of these, so that they can agree the exact shape of the uniformities that apply in

⁵ For example, Russians discriminate two different colours what the English classify as different shades of blue.

the situation they are inⁱ. Our framework traces the information flow between them that leads to the interpretation that the mother is the baby's mother and that she picked the baby up because it cried. There are many other features that can (and in a complete analysis should) be taken into account, such as speaker choice of expression, linguistic – semantic and pragmatic, aspects of the two utterances, rhetorical characteristics of stories. However, in this discussion we will concentrate only on those features that seem to be the most relevant to the explication of tacit knowledge shared by those who hear the 'story' and interpret it in the way Sacks observes.

Thus our analysis of the two sentences 'The baby cried. The mother picked it up.' formulates the information structures and relations that enable us to show how agents may utilize tacit knowledge in co-action. The relations that apply in a given situation represent the regularities that the agent discriminates. The underlying structural form is based on the assumptions that the agent recognizes actual situations as instances of situation-types and is attuned to the constraints that obtain between them. Thus when the agent finds itself in a situation s of type S , it knows that there must be a situation s' of type S' . A particularly important feature of this analysis is that it separates clearly the two very different kinds of entity that are crucial to the creation and transmission of information: on the one hand the abstract types and the constraints that link them, and on the other hand the actual situations in the world that the agent either encounters or whose existence it infers.

The word 'baby' in everyday use can refer to a young individual, a family member, a person who is particularly dear to the speaker, an individual that a pop song is about, and many other potential meanings that depend on the particular context in which it is used. In our analysis, the individual denoted by the word 'baby' is recognized as a type T_{baby} , which belongs to T_{family} and $T_{\text{stage-of-life}}$. In T_{family} there are also T_{mother} and T_{father} , and so on, while in the $T_{\text{stage-of-life}}$ there are T_{child} , $T_{\text{adolescent}}$, T_{adult} , and so on. Thus we can capture different aspects of both 'baby' and 'mother' - who stands in a relation to 'baby' and 'father' for example. These aspects, which affect the choice of words that speakers make and the way listeners interpret them, are captured in our framework by the hierarchical structure on types (type of types, etc.)

The actions of 'crying' and 'picking up', etc. are bound to a particular aspect of the type, so that 'crying' ties with the 'baby' in the stage-of-life. When the listener processes the sentence 'The baby cried.' he will understand that $T_{\text{baby}} : T_{\text{stage-of-life}}$. That is to say, this item of information will be available to the listener as he processes the incoming utterance, and will influence the way the input is interpreted.

Since the uses of types in other disciplines (such as computer science) are generally rigid in nature, we should stress that in situation theory, any type will typically be a member of an entire structure of types, and the applicability of a particular type may well depend upon two or more levels in the of-type hierarchy. For instance, the applicability of the type T_{baby} will be different when it is considered in the light of being in the type $T_{\text{stage-of-life}}$ as opposed to being in the type T_{family} . In the former case, individuals of the type T_{baby} will be typically and naturally associated with the action of crying (type T_{crying}); in the latter case they will be typically and naturally associated with have a mother (2-type $T_{\text{mother-of}}$). In situation theoretic terms, these associations will be captured by constraints that link types. Those constraints are in general not universals, rather, they may depend on individual, or maybe cultural factors.

Since the opening of the story is a communicative act, the situation theoretic perspective is that any such act refers to a *described* situation, the part of the world that the communicative act is about. The described situation may be determined in any number of ways – the speaker may have observed, or read about or imagined it, but in either case, it provides contextual boundaries within which real-life individuals and situations may be recognized as types.

3. Application in the Design of Organizational Memories

New technologies such as multimedia, mobile telephones, wearable computers and video have the potential for supporting the working environments that are characterized by professional and cultural diversity. “It is important that this technology fits in unobtrusively with the working practices of particular communities, supporting the interactions and activities that have naturally evolved as part of social life in the workplace “ (Winograd & Flores, 1986).

Natural interactions follow a general pattern; the participants establish contact, make their situation visible to others and then together build a shared environment where they co-operate to solve the current problem (cf. Gumpertz & Hymes, 1972). Participants co-ordinate their actions and focus on common artefacts (for example documents, drawings or a computer screen) in the process of negotiating the meanings of words or images presented there (Robinson, 1993). They thus create the common ground – “a sine qua non for everything we do with others... the sum of [the participants’] mutual, common or joint knowledge, beliefs, and suppositions” (Clark 1996, p 92)

Within the boundaries of the common ground the participants can identify the objects referred to, come to understand each other’s goals and purposes, co-operate and co-ordinate their actions. Indeed, common ground is regarded as fundamental to all co-ordination activities and to collaboration (Clark & Brennan 1991). Assuming that common ground is fundamental, it is important for the designers of technology to understand what representations should be used in order to design better support technologies.

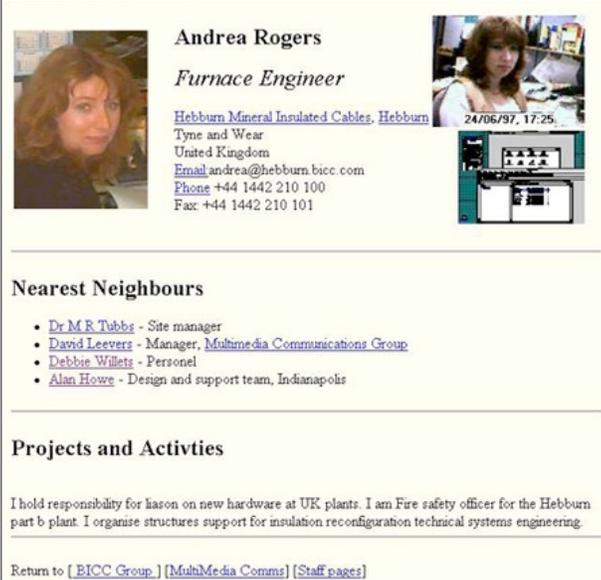
In this context, one of the key research questions is how people create the common ground in situations where the contact between them is influenced or mediated by technology (Rogers, 1993; Hindmarsh et.al., 1998, Dourish & Bellotti, 1992). Usable interactive technology is expected to facilitate the processes that shape human cognition and communication in the significant social and cultural contexts, thus fitting in with normal human activities in the workplace. The working assumption behind the People and Information Finder, as an example of usable interactive technology, is that it forms an integral part of the entire information environment created by the interaction of people, organizations and artifacts where information is generated, exchanged, stored, processed, internalized and externalized.

The People and Information Finder is a multimedia prototype developed as part of the CICC project (Collaborative Integrated Communications for Construction, ACTS No. 017) focused on the development and use of interactive technology in the workplace, particularly in large-scale construction projects. The research is user-driven and interdisciplinary. It is motivated by the needs of people working in construction and manufacturing industries, where poor communication causes serious problems in day to day activities which require continuous cooperation and coordination (Fruchter, 1998).

Interactive multimedia technology is designed to improve communications and to offer a richer information environment for the repair of breakdowns and misunderstandings. Such a facility is particularly useful in agile project teams, where a stable organisational form is absent. For example, in construction, the team is created for the purposes of a particular project and is dissolved once the project is completed. The work on the project itself represents a period during which cooperation is vital. Problems of lack of shared culture have to be addressed and this is usually done with a series of induction meetings and seminars at the start of the project. This is a vital yet time consuming team building stage of the project, and is undermined by teams joining projects at later stages with consequent integration problems (Rosenberg *et. al.*, 1997).

One of the key roles for the People and Information Finder (PIF) is to help those who need to learn about a given project and its organisation, in order to assimilate the project culture without disturbing the established flow of activities on the site. The main research questions concern the content of multimedia displays and their informativeness, both in general and in task-specific situations.

In this context the PIF can be viewed from several perspectives. As a technological artefact it is a web page populated with information about its owners using standard web technology and programming in html underpinned by Java script. It represents a technological platform, more precisely, a configuration of communications technologies such as telephone, network technology such as the web, and advanced interactive technology, such as virtual and augmented reality. It thus provides an integrated service that helps the user to choose between various channels of communication, from voice link to videoconferencing, and to browse through a collection of similar pages created by different owners according to a pre-designed template.



Andrea Rogers
Furnace Engineer

[Hebburn Mineral Insulated Cables, Hebburn](#)
Tyne and Wear
United Kingdom
Email:andrea@hebburn.bicc.com
Phone +44 1442 210 100
Fax: +44 1442 210 101

24/06/97, 17:25

Nearest Neighbours

- [Dr M R Tubbs](#) - Site manager
- [David Leevers](#) - Manager, [Multimedia Communications Group](#)
- [Debbie Willets](#) - Personnel
- [Alan Howe](#) - Design and support team, Indianapolis

Projects and Activities

I hold responsibility for liaison on new hardware at UK plants. I am Fire safety officer for the Hebburn part b plant. I organise structures support for insulation reconfiguration technical systems engineering.

Return to [[BICC Group](#)] [[MultiMedia Comms](#)] [[Staff pages](#)]

Fig 1 Home Page

Another perspective is that of multimedia displays of information, designed to provide a richer experience of people and their work environment in a particular organisation. The

structure of a PIF web page reflects the findings of workplace studies that within such a work setting, information is normally obtained from people, from artefacts such as documents or databases, or from the real world where PIF owners live and work. The basic PIF page is divided into three main components. The first contains information that helps visitors to locate the owners in their physical space, such as name, address, phone number and email address, as well as photographs and video images showing their offices, desks and terminals. This makes it possible for the visitor to choose how to contact them, via telephone, ordinary mail, email or videoconferencing. The second, Nearest Neighbours, provides information about the organisational space that a team occupies, giving similar information about accessing other PIF owners who are engaged in similar or related work. The third component describes the owners' projects and activities, both present and past, comprising of the part of the real world in which the owner's work is done.

The PIF thus provides a uniform platform for accessing information about an organisation or a team in the construction industry, the people who work for it and the activities they engage in. The status of information ranges from personally owned (or private), which is accessible only to the owner, to the information that is distributed (or shared) between members of a group. Alternatively, information may be public (or visible), which the owner is willing to show to the general public or to a selected group of collaborators. This non-proprietary information forms part of the informational resources used by the organisation or the group as a whole.⁶

The PIF, as a specific form of multimedia, has the potential for enabling innovation in co-operative work within agile teams. In order to understand better this potential a preliminary study of communication mediated by the PIF prototype was carried out in interviews with a small group of informants. The main aim was to find out what general interactive strategies people use when learning about a team, its people and their work. In particular, the focus was on discovering what knowledge, presuppositions and beliefs people bring with them to joint activities, and how the external representations designed in the PIF could influence the creation of the common ground.

In the analytical framework developed for the study of the PIF use in a real-life setting, we distinguish two areas of joint activity, process and content (Clark & Brennan, 1991; Grosz & Sidner, 1986; Clark & Schaefer, 1989). In the process or task activity team working between the members is carried out by means of communication. The content, centred around the design or media object, is the topic of the interactions and the focus of the work. Process comprises actions on tasks (e.g. finding new tasks, justifying them and checking they have been done), responsibilities, abilities, and negotiated authority. Content comprises actions on design or media objects (e.g. showing a file or drawing), the design or media objects themselves, and organisational authority (Sillince & Rosenberg, 1999).

In this paper, the focus is on content, more specifically on the informational content of a PIF page and the ways it can help new members of a construction team prepare for joint activities that take place in the course of the construction project. It is regarded as a medium for external representations of the common ground that the owners of PIF pages share with their visitors.

⁶ The team involved in the development of the PIF prototype consisted of Nicholas Farrow, David Leever, Mark Perry and Duska Rosenberg (cf. Rosenberg et al., 1997).

Many joint activities in construction are carried out “at arm’s length”, instead of face-to-face, where the possibilities of misunderstanding are greater and the facilities for repair reduced. It is therefore important for the communications technologies to observe the established representations of information in terms of rules, regulations and etiquette that is easily accepted by team members. It is even more important for the technologies to enhance the representations of information to include more personal and less structured requirements, such as helping people to build trust.

In this study the informants, visitors to PIF pages, were observed in a “conversation-at-arm’s-length” with the PIF owners, where the main goal was to learn about the “PIF people”. Their responses were elicited in open and in structured interviews, as well as focus groups. The data analysis was oriented towards explicating the informational links between what visitors could observe in the communicative situations displayed on the PIF pages and how they interpreted the information presented there.

The observations of informants' navigating through the PIF sample were focused on the ease of use and on the extent of the support for learning that it offered. Two main research questions guided both the data collection and the interpretation of the informants' responses. The first was concerned with the informativeness of various PIF pages in terms of content. The second question was whether or not the principles that govern social action and face-to-face interaction in the real world would be equally valid in the mediated interaction in the media space and the virtual world.

4. Representations

4.1 The Physical and Social Spaces

The information the PIF visitors picked up from web pages was considerably richer than that explicitly expressed. Much of this richness was related to the social and organisational characteristics of the owners' physical environment. For example, the god's eye view of the office layout (see Fig 2 below) helped them to infer the social structure of the group inhabiting the space. The assumptions normally made about the social significance of physical spaces in the real world were also made about the virtual world.

Knowledge of the ways in which real organisations structure their working space helped visitors to interpret the social aspects of the situation presented on the screen. For example, they understood that people who have their own offices are higher up in the organisational hierarchy, and that those who are physically co-located usually belong to the same working group. The external representation of the office space thus plays an important part in identifying the owners' status and relationships.

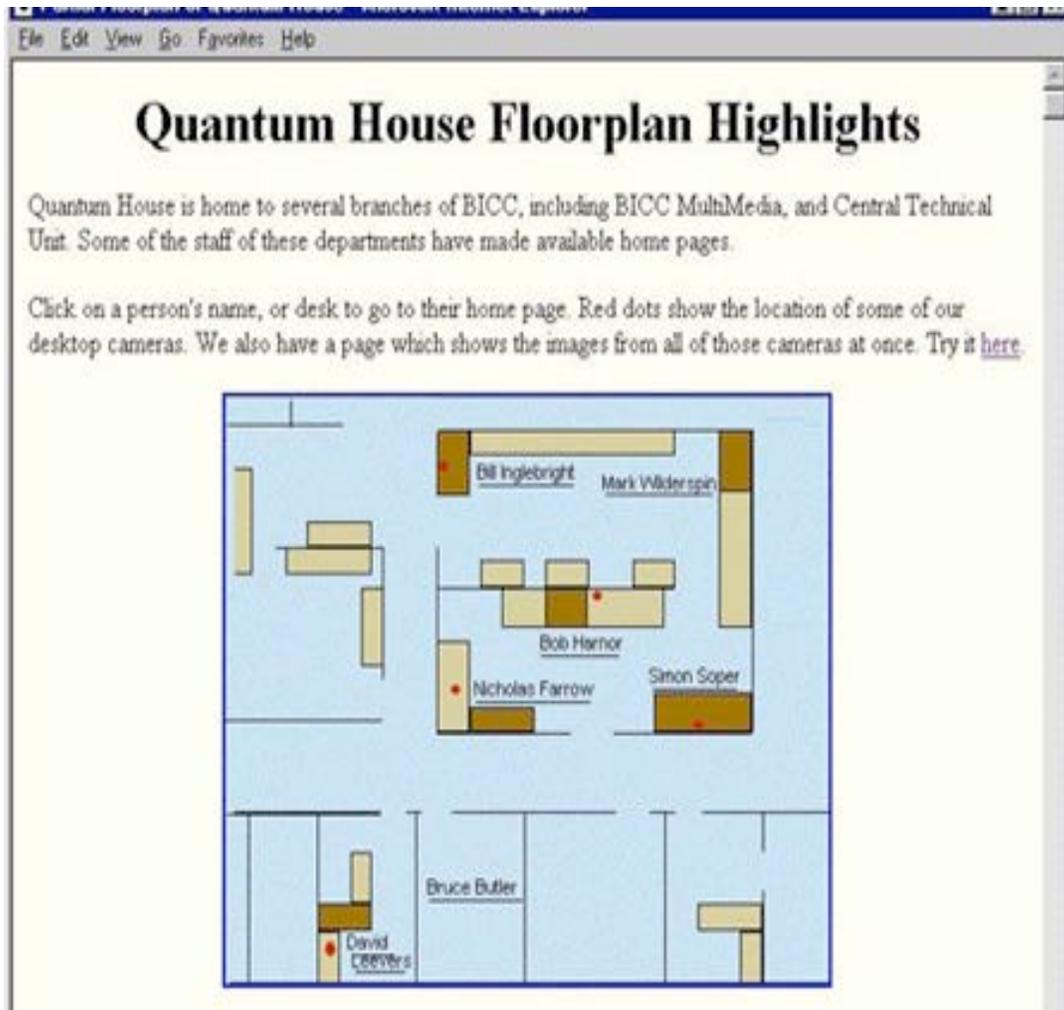


Fig 4 Floorplan

Similarly, the screen presenting the Virtual Multi Media World is effective at a first glance since it promises the experience of virtually visiting the group. It is regarded as a virtual reception area where visitors expect to be directed to particular people and their working spaces.



Fig 5 Multi Media World

4.2 Personal Spaces

Interpretations of individual web pages confirm the importance of links between the images of the physical environment and the socially relevant information inferred from it. Different views of the physical location reflect the personal image of the owner as if she is wearing “electronically augmented clothes”. Photostrip of the office and the view it offers are also helpful in interpreting the atmosphere of the place and sometimes even the character of the owner. For example, the scene of papers scattered all over the desk makes the owner appear as an untidy but a creative person, someone who works with paper and computers, which indicates a high level of education, and might be seen as “serious, reliable and responsible”.



Fig 3 Photostrip

These images are strengthened by the videoglance that allows direct observation of the owners at work, so the visitors can draw their own conclusions about the owner and his or her workplace setting. The members of the group presented here are assumed to be creative, working on knowledge-intensive tasks, spending much of their time at the terminal since there is usually a comfortable chair in front of the computer. The shrunken screen reinforces the image of a person who adopts a structured and systematic approach to a specific task.

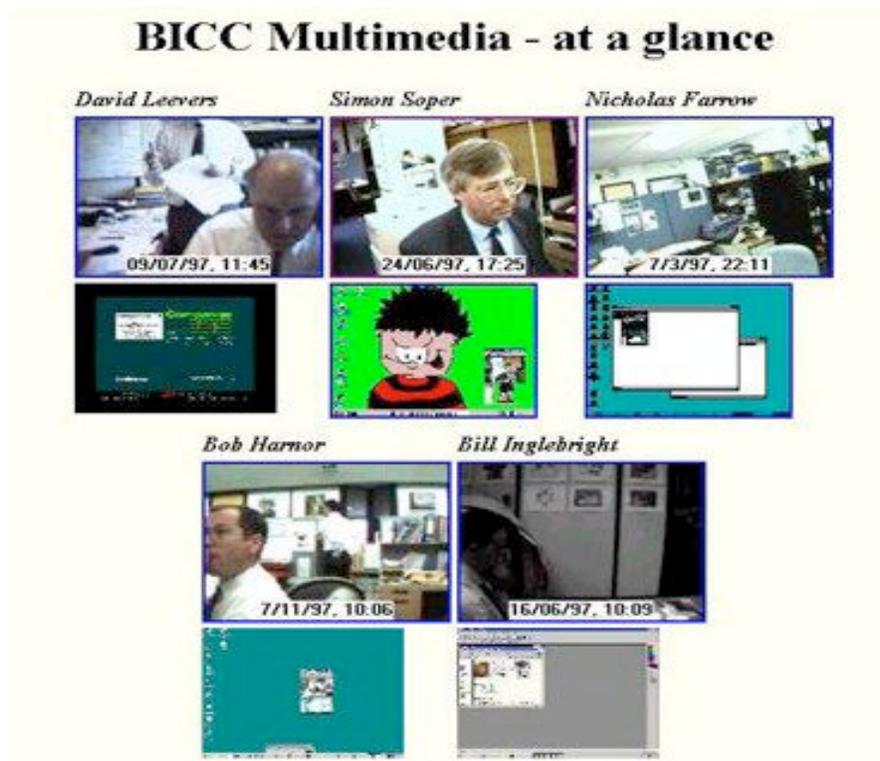


Fig 4 Videoglance

4.3 The Information Environment

Originally, the design intention was for the PIF to provide information about the owners' availability by making their situation at work more visible to potential visitors. The possibility of intrusion into the owner's space at an inopportune time is thus reduced. Videoglance was the main source of this kind of information, which would enable visitors to make informed decisions as to whether the owners should be approached via an intrusive medium such as telephone, or videoconferencing, or whether an email message may be more appropriate.

A particularly impressive feature of the videoglance is the time annotation and continuous updates of the recording when the page is connected to the Web. This helped visitors to decide whether to contact the owner or alternatively one of his nearest neighbours.

Messages left on the screen when there is no activity are a very important guide to availability. For example post-it notices saying "Back this afternoon/tomorrow/next week/" which give immediate guidance as to when the owner can be contacted. A collection of such messages creates the context for interpreting similar situations when there is no action on the screen. Thus the view of an empty office without a message would mean that the owner is momentarily absent, perhaps talking to a colleague in the corridor or having lunch, while

the message saying "Goodbye" would mean that a longer, or maybe indefinite period of absence was intended.

People who share the working environment with the owner can provide an alternative point of contact if the owner is not available. Particularly useful features are the links with closest collaborators within the intellectual space they share, indicating to the visitor that close collaboration is no longer restricted to people inhabiting the same physical working space. The PIF is therefore an informational resource that can transcend the limitations of the real world and this is where the visitors saw possible new uses of this technology in their own lives. The general image was that of an impressive technological achievement providing a novel service.

The wealth of information provided by the virtual VideoOpenPlan enables visitors to decide whether to establish contact with a particular person or not. The overriding principle in visitors' deciding who to contact was the awareness that they may be intruding into other people's working spaces and they were therefore looking for signs of invitation. In general, they expected a virtual host to help them orient themselves in the organisational environment and to act as a focal point to which they would return when they get lost in the virtual space they were navigating. The host was also expected to sanction the appropriate forms of contact and determine the acceptable degree of intrusion in any given circumstances.

Particularly important was the realisation that the owners had full control over the videoglance, so when they did not wish to be watched they could turn the camera off. This meant that if the camera was on, the visitors were invited to enter, but they were still aware of different degrees of intrusion possible in the circumstances. For example, accessing a database or clicking on a document was equivalent to a permission to "enter without knocking", sending an email message was comparable to leaving a message on the door, but videoglance helped with the choice whether to knock or not. Videoconferencing, being the most intrusive call for contact required the most explicit permission.

The scenes offered by the videoglance were interpreted in the light of such social considerations. The "degree of closeness" between the owners and the visitors was often determined by interpretation of symbols, such as a highlighted name in the nearest neighbours section was seen to be an invitation to contact that person rather than somebody else. Rules that are observed in face-to-face interaction also played a part in decisions to establish contact, so that people whose faces were turned towards the camera were generally considered to be more friendly and approachable.

5. Context

Most visitors saw the PIF as providing much more than a home page on the web. They used it as a travelling map that helped them to locate the owners within the wider context of their organisation. The context was referred to simultaneously as the physical and the informational space the owners occupied. The global function of the PIF from the visitors' point of view is that of an augmented map which enables the view of individuals in relation to their neighbours and to other sources of information available in the real and the virtual worlds.

Learning is seen to depend on the visitors' understanding of the PIF structure and on their expectations as to what the underlying services will provide. The structure of a PIF page

facilitates learning about people and their immediate working environment since visitors are able to obtain information about the owners and the impression of their working environment. The combination of concise text and photographs, with living images provided by the videogance is particularly effective as an introduction to "the real people and places".

Informativeness of the PIF prototype is an important factor to ensure its relevance to the visitors. The quality of the individual pages is judged in terms of both their content and representation. Information about the group, personal details of its members, their immediate working environment, the physical and logical space of individuals within the organisation, as well as the projects and activities they have been involved in all contribute to the acceptance of the PIF as an informational resource.

In this study the informants' browsing through the PIF pages of the Multi Media group was curiosity-driven. However, the findings of the previous workplace studies at two other construction firms suggest that such a general-purpose informational resource can be useful in providing an introduction to the construction project for clients, local community representatives as well as newcomers to the project. The reactions of the viewers overall suggest that PIF can be easily adapted for marketing and publicity purposes as well.

The results of this preliminary study provided the basis for specific hypotheses about the social and cultural knowledge that plays a part in determining the potential of the PIF to enable community building across multi-branch organisations. These will be tested further in task-specific situations. The findings will be used to refine the design of the PIF prototype prior to its introduction into real-life settings where it is expected to become the core of an informational environment for organisational learning.⁷

Several principles which govern social interaction in establishing face-to-face contact also apply to the situation of virtually visiting an organisation and its people using the PIF. The PIF makes a person's environment visible to others at remote locations, and helps in creating a common ground to underpin joint activities. An important social (and design) principle is related to intrusion into another person's space, be it physical, organisational or informational. Invitations into such spaces can be communicated indirectly and visitors will look for them in the objects presented in the page, such as the videogance, shrunken screen and highlighted names. This will happen even if the designers of the page have not explicitly intended for these objects to have such a communicative function.

Another important principle concerns interpretation. Visitors' interpretation of the information presented on a PIF page will be considerably richer and with more social detail than the literal meaning of the text, pictures or graphics presented. This is where the metaphor of 'electronically augmented clothes' is particularly apt. Decisions are made not only about the appropriate means to obtain information by accessing the sources that the PIF makes available, but also about personalities and possible relationships between them, the nature of the organisation and maybe even the quality of work that can be expected of them.

The information displayed on the PIF pages is therefore interpreted within a rich context of natural human communication, where the accepted social norms that determine appropriate behaviour apply. The analytical framework developed here provides the conceptual basis, as

⁷ Another use of the PIF will be to present and visualise the content of academic and industry-based research and profile the researchers and their working environments both at the MMG, BICC and the i.e. centre, Brunel University. This is part funded by the Nuffield Foundation.

well as methods and techniques for discovering and formulating the social constraints that regulate joint activities and communication at arm's length. It is the framework for the design of technology that brings together people, their social relationships and the resources they need in order to carry out the joint activities in the workplace.

6. Application in computer-mediated communication

As a starting point in the application of the information-based model, we take the concept of information in its everyday use and make it more precise by way of mathematical definition. We use that additional precision to examine in some detail the distinction between explicit and tacit knowledge of an organization. More specifically we focus on a distributed organization where information and knowledge flows are mediated by technology and examine the impacts of mediation on the sharing of tacit knowledge.

Shared artefacts are an integral part of the entire information environment created by the interaction of people, organizations and resources where information is generated, exchanged, stored, processed, internalized and externalized. The research into knowledge sharing is user-driven and interdisciplinary. The specific case study reported in this paper was motivated by the needs of people working in construction and manufacturing industries, where poor communication causes serious problems in day to day activities which require continuous cooperation and coordination (Fruchter, 1998). Interactive multimedia technology was designed to improve communications and to offer a richer information environment for the repair of breakdowns and misunderstandings (Rosenberg and Sillince, 2000). Such a facility was found to be particularly useful in agile project teams, where a stable organisational form is absent. For example, in construction, the team is created for the purposes of a particular project and is dissolved once the project is completed. The work on the project itself represents a period during which cooperation is vital. Problems of lack of shared culture have to be addressed and this is usually done with a series of induction meetings and seminars at the start of the project. This is a vital yet time consuming team building stage of the project, and is undermined by teams joining projects at later stages with consequent integration problems.

The empirical study identified three key aspects of the work environment – people, place and process – that jointly influence the functionality of the technology supporting agile teams in this kind of collaboration. Bearing in mind that their organisational structure is continuously changing, the changes directly impact patterns of collaboration between individual members of agile teams. A unified “Human Environment Framework” was developed (as part of the SANE project) to examine the role of information and communication technologies in the workplace of the future. Particular emphasis was given to knowledge sharing in mediated settings where technology provided essential resources for communication and collaboration.

The relationships between the three perspectives, people, place and process, were captured by means of constraints to create a described situation that provided the work context for individual interactions. Technology requirements in that context were then specified in terms of the desired functionality of the shared artefact. This could be an application such as the database, or a representation of shared information on the screen such as virtual or augmented reality - in fact, any shared artefacts from a broad range of resources that may facilitate collaboration and knowledge sharing.

A very simple example of the situation S_1 involves people working in the same team, on the same task at the same location thus requiring a work space that provides a setting so that they can establish clear boundaries with people outside the team, but still enables full knowledge sharing within the team. If there are changes in the location, so that in S_2 some members of the team are remote, then resources are required to maximize presence through the appropriate use of multi-media, virtual reality and other ICT applications. Technology support is thus defined in terms of its functionality – increasing presence – and usability parameters can be discovered through more detailed empirical or experimental evaluation of potential technology solutions. If the changes are in the composition of the team, and in S_3 the members of the team are from different organisations (for example, consultant and client) then the mediated setting needs to provide sufficient privacy and local control of information channels in order to preserve confidentiality. The functionality of the ICT applications in this context has to be focused on establishing boundaries within the team so that people can negotiate the kind and the extent of information and knowledge sharing. If the changes are in the task, so that in S_4 people from the same team or organisation share the same physical space but work on different tasks, then increased privacy is required in order to minimize interruptions.

This, albeit simplified, example illustrates the kind of functionality features that make it possible for us to understand how ICT solutions may be dynamically configured in a changing workplace context.

In real-life, however, this context is considerably more complex than the time/space matrix can account for. Once the social and the work dimensions are included in the characterization of work spaces, we find that a wide variety of ‘inter-locking’ spaces need to be made available. In the case of mobile work, we encounter various combinations of private-in-public space created by a person writing a report in an internet café, or privileged-in-public created by an ad hoc team meeting in an airport lounge. What all these work settings have in common is the interdependence of physical, social and work aspects of the workplace, be it real, virtual or hybrid. Our information-based model contributes to the analytical approach that can help us to design technology to be embedded in such a workplace. ICT, and in particular its advanced and specialized forms, such as location, or context aware applications have to be designed to observe such privacy and confidentiality constraints.

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ⁱ A *situation* can be thought of as a limited part of reality with a structure whereas individuals do not have such a structure. Information is always taken to be about some situation, and is taken to be in the form of discrete items known as *infons*. These are of the form

$$\langle\langle R, a_1 \dots a_n, 1 \rangle\rangle, \langle\langle R, a_1, \dots, a_n, 0 \rangle\rangle$$

Where R is an n -place relation and a_1, \dots, a_n are objects appropriate for R (often including spatial and/or temporal locations). These may be thought of as the information item that objects a_1, \dots, a_n do, or, respectively, do not stand in the relation R . Infons are items of information. They are not in themselves true or false. Rather, a particular item of information may be true or false about a certain part of the world – a situation. Thus it can be said that the infon σ is an item of information that is true of the situation s , or to put it another way, that s **supports** σ . Indeed, for every positive infon there is a dual negative infon that can be thought of as the opposite informational item, and both of these cannot be true in the same situation.

Situation theory provides various mechanisms for defining **types**. The most basic methods are type-abstraction procedures for the construction of two kinds of types: situation-types and object-types. Type abstraction is a process of obtaining a type from a situation parameter and a compound infon so that we can specify the situation-type in which the infon obtains. Object type includes the basic types TIM, LOC, IND, RELⁿ, SIT, INF, TYP, PAR and POL which are determined over some initial situation. In object-type abstraction, if a situation supports some compound infon involving an object parameter, then we can determine the type of all those objects to which the object parameter can be anchored. The situation s is the **grounding** situation for the type and in many instances the grounding situation is the world or the environment we live in. Thus the grounding situation is typed from the outside, whereas the situation-types classify situations according to their internal structure.

Types and type abstraction procedures provide a mechanism for capturing the fundamental process whereby a cognitive agent classifies the world. Applying the distinction between situation types and object types to knowledge phenomena, we may say that we all recognize that the relationship between **situation-type** *fire* and the situation-type *smoke* obtains only if both are in the same place and at the same time. This is then a part of the shared knowledge among members of the same group or community that is often assumed and therefore rarely articulated. Situation theory offers a mechanism for articulating these assumptions by means of defined constraints. **Constraints** provide the situation theoretical mechanism that captures the way that agents make inferences and act in a rational fashion. Constraints are linkages between situation-types. They may be natural laws, conventions, logical (i.e. analytical) rules, linguistic rules, empirical law-like correspondences, etc.

For example, people are familiar with the constraint ‘smoke means fire’. If S is the type of situations where there is smoke present, and S' is the type of situations where there is a fire, then an agent can pick up the information that there is a fire by observing that there is smoke and being aware of, or **attuned to**, the constraint that links the two types of situation. We can thus say that S **involves** S' .

Constraints link types, not situations. However, any particular instance where a constraint is utilized to make an inference or to influence action will involve particular situations. Thus a constraint that S involves S' allows an agent to make a logical inference, and hence facilitates information flow, as follows. First the agent must be able to discriminate the two types S and S' . Second, the agent must be aware of, or attuned to the constraint. Then, when

the agent finds itself in a situation s of type S , it knows that there must also be a situation s' of type S' .

A particularly important feature of this analysis is that it separates clearly the two very different kinds of entity that are crucial to the creation and transmission of information: on the one hand the abstract types and the constraints that link them, and on the other hand the actual situations in the world that the agent either encounters or whose existence it infers.