Proceedings of the Third European Conference on Computer-Supported Cooperative Work
13-17 September, 1993, Milan, Italy
G. De Michelis, C. Simone and K. Schmidt (Editors)

Bringing Media Spaces into the Real World

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Abstract: This paper describes a field study to evaluate the use of audio and video connections in a "real world" setting, that is a distributed product development organization within a large multinational corporation. We installed two types of media space connections: a focused dial-up video-phone for engineering problem solving between designers in England and the shop floor of a factory in the Netherlands and an unfocused "office share" to support administrative tasks. We observed that users quickly integrated the new video links into their existing media space of telephone, beepers, answering machines, video conference, fax, e-mail, etc. Users easily learnt how to shift from one medium to another. This suggests that "real world" media spaces should be designed to allow a user-driven smooth transition from one medium to another according to the task at hand and the bandwidth available: from live video to stored video, from moving video to still frames, from multimedia spaces to shared computing spaces for synchronous sketching and asynchronous message posting, and from two user conversation to multi-user conference calls.

1 Introduction

A number of research organizations have explored the use of media spaces, which provide distributed users with access to each other via video and audio links (Bulick *et al.*, 1989; Fish *et al.*, 1993; Olson and Bly, 1991; Gale, 1991; Buxton and Moran, 1990; Ishii and Kobayashi, 1992; Mantei *et al.*, 1991). A survey of such research can be found in Bly *et al.* (1993).

The study was conducted in cooperation with British Telecom Laboratories and has been partially supported by the European Community EuroCODE project within ESPRIT III.

The EuroPARC media space is called RAVE and has two main characteristics: first, everyone in the lab, including administrative personnel and researchers on other projects, participate in the media space in their everyday life. Second, RAVE offers the flexibility to shift from peripheral to focused views of the technology (Gaver *et al.*, 1992). The RAVE system offers a range of interaction modes which can be ordered in a scale according to the decreasing level of engagement required: *video-phone*, a two-way connection between two nodes; *office share*, a two-way video connection active for a long time; *glance*, a 3-second one-way connection to one selected office; *sweep*, 1-second connections to various nodes; *background*, one-way view of a public area. These communication modes evolved over time and reflect how individuals in the lab balanced the trade-off between protecting their privacy and increasing their awareness and ability to interact with each other.

We were interested in the next step, which is to bring media space technology to a real user organization. From a technological point of view, the difference between the RAVE system at EuroPARC and the installations described in this paper is that the former is based on traditional analogue video technology (consumer cameras and TV sets, analogue video switch and kilometres of coaxial cable), whereas the latter is based on recent digital technology (ISDN and TCP-IP networks, CCITT H.261 video compression, RISC workstations). The RAVE analogue technology provides PAL quality video but only within the building, whereas the digital technology we used for this field study delivers lower quality video but uses less bandwidth, making it affordable for international links.

This study had three primary goals: i) To discover the thresholds of acceptable video quality for various kinds of media space connections given the bandwidth and cost constraints of long distance links in the "real world". ii) To learn from users and how they reinterpret video technology for their own purposes in the context of their daily work. iii) To develop guidelines for the design of future media spaces.

2 Research Study: Phase 1

This study was conducted in two phases over a period of one year. Researchers from Rank Xerox EuroPARC and British Telecom Laboratories conducted the Phase 1 interviews with members of a design organization and a manufacturing site. Phase 2 involved the installation and evaluation of two video links between these two sites.

2.1 User Organization

The organization is a large multinational manufacturing firm. The European design centre, located in England, has approximately 600 people who are responsible for the design and management of products for sale within the European Community. The organization is structured in a matrix with two dimensions: functions and projects. They work closely with manufacturing centres located throughout Europe, as well as some in Canada and South America. This company is characterized by the typical pressures of high-tech companies in an innovative, competitive and turbulent market: increase customer satisfaction, maintain a technological edge, improve quality while decreasing costs. Product development, in particular, is under great stress: reducing the time-to-market, streamlining processes, concurrent engineering, adapting to fast technical change and efficient use of resources are issues faced at all levels. Process issues are continually readdressed to find new ways to manage the trade-off between accountability and meeting deadlines.

The organization operates as a highly distributed working environment. Some designs originate in Japan or in the U.S. and European versions are created for the European market. A particular product may be designed in England, with components built in France, Canada and the Netherlands, with the final assembly in the Netherlands and a separate conversion process in Mexico. The management control of such a product begins in England during the initial design stages and then transfers to the key manufacturing site. After the product launch, both the designers and manufacturing engineers follow the customer reaction to the product and make changes in the manufacturing process as needed.

The organization uses a fairly sophisticated telecommunications infrastructure: a corporate telephone system based on leased lines (to reach the other site one dials only the extension, no prefix or country code), voice conference calls, answering machines, beepers, fax, electronic mail and video conference facilities for meetings. All engineers and administrative staff have either a workstation or a computer terminal. Even with this infrastructure, engineers spend a great deal of their time travelling to the other site and large percentages of project budgets may be allocated for travel on major projects.

One of the primary motivations for the user organization's participation in the project was to try to reduce travel costs without affecting the quality of the products. A secondary interest was to see if new styles of working could be developed that would improve communication and increase the effectiveness of the development process.

2.2 Interview Procedure

The interviews had two main purposes: to learn about the needs of the people in the user organization and to identify sites for testing the media space hardware and software. Two researchers from EuroPARC and one researcher from British Telecom Labs conducted the interviews. Each interview was audio taped and transcribed for later analysis.

We met extensively with the director of the division, who is a key supporter of the project. He provided an overview of the organization and arranged for us to meet all of his direct reports and many of the second-level managers. He also met with us after each day of interviews.

We began by making a presentation to the managers that described the media space in our lab and the technology available. We then interviewed 22 managers and staff members. We scheduled an hour for each interview and met in the individual's office. The interviews were open-ended, although we asked a set of basic questions of everyone, including their role in the organization, a description of their work, the communication breakdowns they faced and the current strategies for addressing those breakdowns. Finally, we asked each of them to give a recent example of their use of the existing video conference facilities and their general opinions of it. In addition to the interviews, we attended a number of regularly-scheduled meetings, attended by people from each site either live or using video conference.

2.3 Existing Video Conferencing System

Based on the interviews described above, we identified the basic communication patterns within the organization. Here we summarise our findings about the use of the existing video conferencing system. We expected that users would compare the new video links with the existing video conferencing system. As video conferencing is often not very successful for various reasons (Egido, 1988), we were interested in finding out what users thought about it.

The user organization has invested heavily in a corporate television system (CTV) which provides video conferencing facilities at most US and European sites using a mixture of satellite and cable links. Users sit at a long table that can accommodate six people and two video cameras capture each group of three people. In addition, a ceiling-mounted camera provides facilities for transmitting video of a document or object. The users see their remote colleagues on two large video monitors located opposite their table. A third monitor in the middle shows documents from the remote site. (One user said it felt like being on a quiz show on television with the opposing team lined up opposite them.)

The most common use of CTV is a project checkpoint meeting, which has priority. Anyone, however, can schedule a meeting when the room is not already booked. Project meetings are scheduled months in advance and are highly stressful. If successful, the project team receives approval to proceed to the next phase of the project, otherwise the project slips –a highly undesirable outcome. Another common use of CTV is to address critical problems that arise, i.e. those which might make the project slip. These meetings usually involve technical people who know each other. They rarely look at each other, but make use of the ceiling camera to discuss design documents. They cannot discuss the products directly, because there are no facilities for bringing hardware prototypes into the meeting room. There are also no associated computer facilities for sharing electronic documents.

Users expressed mixed reactions to CTV. Some people (usually high-status managers) found it very useful. They tended to be in control of the meetings and found CTV useful for saving travel costs. For example, during the Gulf war, all cross-Atlantic travel was eliminated. One manager said:

> CTV really came into its own during the Gulf war; [its] use has really increased since then.

Other managers found it useful as well:

> CTV is good for sharing problems and project status; for general information exchange.

> CTV is pretty effective... but the 3-4 second delay is off-putting. Also the cross-talk if the time is not sufficient. It's best if it's group to group, rather than just two people talking.

However, most people found CTV to be divisive and felt that it increased the adversarial nature of the relationship among the participants. These users tend to be the individual contributors who must use the system to negotiate issues and solve problems. Several people described their concerns as follows:

> CTV is a strange medium – nothing beats face-to-face... For some types of individuals there is lots of friction. If people [already] have positions, being able to see them doesn't help to bridge the gap. You see a panel of people; it's a stand-off situation. It encourages antagonism.

> I am anti-CTV. It gets adversarial, like university challenge... It's ok to communicate stuff that's already happened.

One user pointed out the problems when more than one site is connected via video conference:

> My group has a regular CTV session with all the regional design centres, but it's not successful really. One control center can view another [but] the other sites can only hear the others on the phone. So they get the lion's share of the activity. We need better multi-site control.

The mechanics of using video conference can also be a problem:

> It's a hassle to make bookings and walk to K building [the location of the CTV meeting room].

In summary, most people viewed face-to-face meetings as the optimal form of communication, but were tired of the amount of time they took and the amount of resources spent in travel. CTV was viewed as useful, especially by management, but tended to create antagonism among the participants. We were interested in seeing whether or not a media space could provide better access to each other and reduce the adversarial quality of the interactions found with CTV.

3 Research Study: Phase 2

Phase 2 involved the installation of two different video links and the study of their use. After the analysis conducted in Phase 1, we chose a major product development project in a critical stage within its two-year life cycle. We identified two areas which had the highest coordination and communication needs across the two sites in England and the Netherlands: i) configuration management; ii) cooperation between design engineers and manufacturing engineers on the shop floor, as the first prototypes were produced on the production line.

In both cases, the participants in the link were under tight deadlines and high stress, with extreme communication requirements, which provided a good test of the technology and the concepts underlying it. Furthermore, at the time the field study was conducted, the travel budget was being reduced, so there was great interest in tools for reducing face-to-face meetings.

3.1 Inter-office Link between Planner/Analysts in England and the Netherlands

The first link was designed to support the planner/analysts who are responsible for configuration management. They must maintain an accurate inventory of the thousands of parts which make up a product, which includes keeping track of design changes for each part and evaluating their cost. Although one person is located in England and the other is in the Netherlands, they must keep in constant contact to track changes as the design drawings are received, approved and entered into the database. The planner/analysts at the two sites exchange a lot of information every day and share many online databases. Although planner/analyst is an administrative position with a low hierarchical status, planner/analysts have a key role for all engineers involved in a product development project because they are a bottleneck for handling changes: all change requests must be submitted to them. They register each request, evaluate the cost and submit it to the Change and Control Board (CCB). The CCB meets every Tuesday morning using the video conference facility between England and the Netherlands. At this meeting senior management review all change requests and decide whether to approve them.

The design and manufacturing engineers must be able to work with the most up-to-date drawings possible, yet changes in drawings require a set of approvals that take time. At any point in time, the engineers must decide whether or not a particular drawing change is likely to be approved and take the risk of going ahead with it. If the engineers went strictly by drawings that were officially approved, the project would grind to a halt and large amounts of money would be lost, since incorrect items would be made. The planner/analysts must thus understand what the engineers are "really" doing as well as the "official" state of the drawings. They process thousands of changes in the course of the project and have 30-50 changes under consideration at any point in time. During critical phases of the project, these two are in telephone contact an average of 30 times per day.

3.1.1 Technology

We designed the first video link to provide the two planner/analysts with a constant video connection throughout the working hours of every day. This corresponds to a slow version of an office share in the RAVE media space (Gaver *et al.*, 1992). An office share provides a constant video connection via a small screen or window. The purpose is to provide an unobtrusive way to stay in touch with the remote person without demanding a focussed social engagement. An office share link stays in the periphery of attention and creates a shared awareness among the people connected, who get a feeling of where the other person is and what he/she does without disturbing each other.

Figure 1 shows the first video link between two Sun workstations. In order to provide a constant video connection across countries we could not afford a dial up ISDN link nor a new leased line. The only affordable bandwidth we could find was the corporate TCP-IP network, based on existing leased lines at 128 kbps. To establish the video connection we used two Sun Videopix video digitizing boards running two software packages: Vfctool, which comes with the Videopix board, and IVS, a public domain software developed at INRIA.

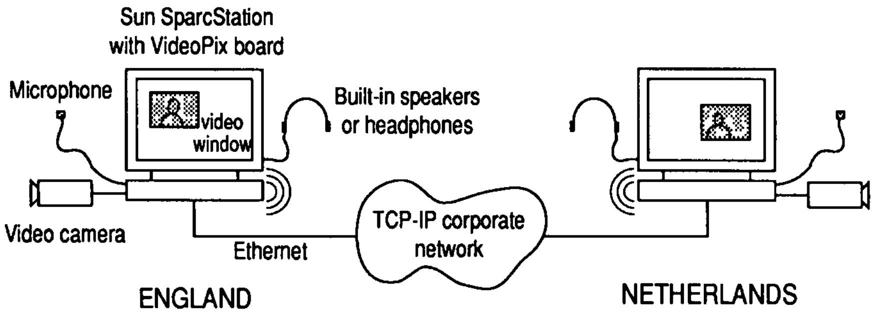

Figure 1. Inter-office Link

Vfctool grabs frames from a video digitising board shared over a local area network. Video frames may be grabbed from one machine and displaying on a remote machine. However, Vfctool does not compress the images, which produces a heavy data stream. Under the average traffic conditions on the TCP/IP network between England and the Netherlands, it took up to 6 minutes to update an image of 320x240 pixels with 8 grey levels, and the software crashed occasionally.

To achieve higher refresh rates we installed IVS, a software package to support video and audio conferences over the Internet (Turletti, 1993). IVS grabs video frames from a Videopix board and compresses them in software on the workstation according to the H.261 standard. IVS transmits the compressed data stream over an IP network using the User Datagram Protocol (UDP) and takes about 20 to 30 kbps of bandwidth. We used QCIF images (176x144 pixels) with 8 grey levels and obtained a refresh rate of one frame every 2-4 seconds. IVS handled packet loss and network overload; the only problem was that sometimes the video window was closed, but the software never crashed and the user could easily restore the link.

3.1.2 User Observations and Results

The inter-office link ran continuously for six days over about one month, during which we installed first Vfctool and then IVS. We spent a few hours observing what users did while the link was up and interviewed the users at various times. We found that the refresh rate of Vfctool was too slow and led to errors. For example, one person thought that the other was at his desk because he could see him on the screen, however when he called him on the phone he found out that he had left a few minutes before. The users enjoyed the link as a new gadget and used it to put up messages in front of the camera such as "Good morning Colin" and "I'll be back at 3 pm", but they did not rely on it as a source of information.

We then switched to IVS, which offered a smaller video window with poorer quality but higher refresh rates. After the initial disappointment about the poorer video quality, the users preferred the new link and kept on using it until the equipment was removed. Even though IVS supports audio communication, the users did not take advantage of this facility but preferred to continue using the telephone on their desk because the audio quality was better.

The users reported that the major use of the IVS link was to see if the other person was busy at his desk before calling him on the phone, which happened several times every day. They could not describe other precise uses, however they said that they liked the office share "because they felt closer". The management evaluation at the end of the project concluded that there were no tangible savings from the specific use of the office share link, and in the final report they wrote: "It's a nice-to-have".

The results of the office share field study are elusive. We need a model of communication to appreciate the meaning and weight of "nice-to-have". An office share can be seen as a medium which specifically supports the *phatic* function of communication (Jakobson, 1960). The phatic function is to keep communication open, to maintain the social relationship between the two partners, to reinforce the physical and psychological connections that must exist to allow cooperation and mutual trust. The phatic function of communication is based on redundancy, which is also the basis of social relations (rituals, conventional behaviour, greetings, tea, beer, etc.); in fact, an office share conveys highly redundant information: the same desk is shown for the whole day.

The best example of how the office share supports the phatic function of communication is the following. The two planner/analysts said they particularly enjoyed the office share on Monday nights, when they have to work late to prepare for the Change and Control Board on Tuesday morning. The configuration managers receive the last data on Monday at 5 pm and work late into the night. When the large open space offices at both sites were deserted and dark after standard working hours, the two planner/analysts appreciated the video link to provide "remote solidarity", to drink coffee together and encourage each other to keep on working until they were done. The video link provided a medium to celebrate the ritual of the long Monday night.

Another way to look at an office share is as a medium to support the communication that takes place by behaving. As the Palo Alto School pointed out, our entire behaviour constitutes a message and since one cannot not behave, "one cannot not communicate" (Watzlawick *et al.*, 1967). An office share delivers behaviour at a distance: not being in the camera view communicates that one is not available, having a lot of paper on the desk communicates that one is very busy, putting the feet on the desk communicates that one is relaxing, etc. All of these messages can be encoded and decoded with no effort or attention by the people sharing the virtual office; in fact, in most cases they are not even aware that communication is taking place, and they cannot stop communicating other than by closing down the link.

It is not surprising that the planner/analysts could not describe precisely how they used the office share link: since they communicated by behaving, it was so natural for them that they were unaware of it. Was communication actually taking place? If we define communication as "anything that changes the probability value of the future behaviour of an organism", then we can find some interesting examples of communication in the behaviour of the planner/analysts. One day during a phone call one planner/analyst mentioned: "Yesterday I saw you were talking with...". The conversation continued without the planner/analysts noticing that the information came from the office share. The link also influenced other people in the open space office; people passing in front of the camera would wave at the other person, and sometimes they asked things like: "Have you seen John around there this afternoon?".

The results of the office share are hard to measure in tangible terms. An office share link creates a virtual office and therefore it produces effects similar to those of building architecture and office layout. It is interesting to observe how easily people adapt to the office share: for a short while users are embarrassed by the camera and "act" in front of it, but after a few hours people forget about it and just behave normally.

3.2 Dialup Video Link between the Engineering Design Centre and the Manufacturing Shop Floor

The second link was designed to support the complex communication and coordination tasks between design engineers in England and manufacturing engineers in the Netherlands. They must transfer and share a large amount of knowledge: the English engineers understand most about product design and the Dutch engineers maintain the relations with the local suppliers. The engineers at the manufacturing site monitor the new prototypes coming off the production line and are the first to see problems. Together with the design engineers, they must decide whether the problem lies in the original design or in the manufacturing process. One of the users' expectations was to use the video link for solving "small" problems arising on the shop floor that require cooperation across the two sites.

3.2.1 Technology

On the English side of the link, we installed one camera clamped on the desktop and one monitor displaying incoming video; for voice we used the speakers built into the monitor and a directional microphone. We also installed a videotape recorder which captured the video coming from the Netherlands and the audio in both directions.

On the Dutch side, the equipment was mounted on a trolley that could be moved around the shop floor to reach various points in the manufacturing line or in the rework area. We installed two monitors (one for incoming and one for outgoing video) and two cameras. One camera was clamped to the trolley and showed a wide angle view of the manufacturing engineers relative to the prototype units on the manufacturing floor. The other was a miniature camera with a flexible cable for showing small details. The people in England could read 2 mm. type sent from this camera. The shop floor had a great deal of background noise, so we used headphones with a built-in microphone.

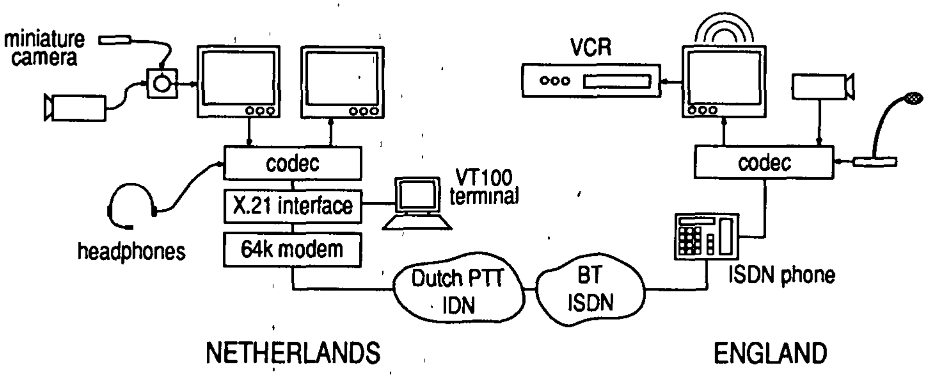

Figure 2. Manufacturing Floor – Design Centre Link

Figure 2 shows the arrangement of the dial-up video and audio link, which was based on two codecs connected by a 64 kbps data line. The codecs implement the H.261 standard and are prototypes of a low end single board model designed for desktop videoconferencing using public ISDN networks. In England the codec was connected to an ISDN telephone via a X.21 interface; the ISDN telephone was used for dialling and for displaying line status messages. In the Netherlands, ISDN was not available in the factory at the time of the field study, so we used a switched 64 kbps IDN line. The lack of a standard ISDN line made the set up on the Dutch side more complicated: a 64 kbps modem was connected to a X.21 controller, which was connected to the codec and to a VT100 terminal. To dial and disconnect the line, users in the Netherlands had to type some commands on the VT100 terminal.

The system had one main problem: it was a research prototype and was not reliable enough for an industrial environment. There were many reasons for the unreliability: we used prototype units of low cost codecs, the codecs were designed for ISDN but in the Netherlands we had to connect it to an analogue 64 kbps line and the system on the Dutch side was constantly moved around the shop floor.

3.2.2 User Observations

The link on the shop floor was available for a total of two weeks. During this period, we spent two days at each site sitting next to the equipment and observing what users did. For the remaining time, we collected videotapes recording the video and audio going through the link and later interviewed the people who used the link. The users tried to use the link eleven times, but could only establish a video connection six times because of the various technical problems described above. The following are examples of tasks carried out using the video link:

- *Packaging problem.* After the design of a part was changed, the packaging for shipping also had to be changed. The change involved making a new cut into the cardboard and assembling the pieces the way that they would fit. Using the video link, a packaging engineer in England was able to show step-by-step how to make the cut and assemble the pieces, with the people in the Netherlands repeating each step at the other site. A problem which would have required a trip was solved in half an hour. When they were interviewed, the users were enthusiastic about the video link and said that it had been particularly useful to do each step of the assembly at both sites, looking at what the other was doing.
- *Software bug.* A manufacturing engineer showed a software programmer in England a software bug by pointing the camera at the display and keyboard of the product so that the programmer could see what was going wrong. Furthermore, the programmer directed the person at the other side to press some key combinations to test some other things, and eventually they found another related bug. The problem could have been described by voice on the telephone, but the manufacturing engineer asked to use the video link because the software programmer was sceptical about the bug: he was confused and thought that the manufacturing engineer was doing something wrong. To actually see the problem and try out some things convinced him of what was happening and allowed him to locate the bug precisely.
- *Paper jam problem.* The paper feed mechanism worked fine on the prototypes, but did not work reliably on some units coming off the manufacturing line. It seemed to be a manufacturing problem, but the manufacturing engineers wanted to have suggestions from the designers. The problem was shown to three designers in England while six people were present on the Dutch side. Many ideas were brainstormed and tested. The main problem in this

case was the audio: we had only one set of headphones in the Netherlands, therefore only the person with headphones could communicate with the people in England.

Users complained a lot about the poor audio quality, the poor video resolution, the lack of reliability of the system. However the engineers were really excited when they could solve a problem using the video link without travelling.

3.2.3 Results

What emerges from the field study is that, in spite of the technical flaws, the shop floor video link did support effectively some tasks. The users had to fight with the technical limits of the system, but they suggested a number of ways to improve the system that are described in section 4. The managers rated the potential for such video links very highly and expected that such links would become an essential part of the infrastructure to support product development. They found it most useful for explaining problems on an *ad hoc* basis or when the problem is unique to a particular machine. Most of the complaints were due to specific problems with the particular installation. If fixed, the overall assessment of the video link would be very high. The following kinds of transactions would be well supported by this type of link:

- *Show a problem.* A manufacturing engineer shows something going wrong on the production line and asks the designers for explanations, solutions, changes, etc. (e.g. software bug). For these types of transactions the video is very important not only to improve communication by adding the visual dimension, but also to overcome the initial scepticism and mistrust. Seeing the problem on video supports the typical discussion where the design and manufacturing engineers tend to blame each other for the problem: is it a design problem, which requires a design change, or a manufacturing problem, which requires retooling or a change in the process? In a situation where distance and difference in nationality between manufacturing and design engineers tend to increase the typical tension between design and manufacturing functions, looking at the problem together helps to foster a cooperative attitude towards solving the problem and "getting things done", rather than arguing an abstract problem over the phone to "pass the buck". This is in contrast to the findings from the use of the existing video conference system.
- *Show a solution.* A design engineer shows how to do something on the shop floor (e.g. packaging problem). The video link allows users to go through each step of the process and to perform it simultaneously at both sites, to make sure that both parties have a full understanding of the solution and its consequences. The advantage of the video link is that it is much faster and much more direct; furthermore, it allows users to see the solution working at both sites which increases confidence in the solution and trust between the two sites.
- *Cooperative problem solving.* A problem is shown and engineers at both ends of the link brainstorm solutions, discuss ideas, point at causes, try out experiments on the machine to find out more and test ideas (e.g. paper jam problem). This is not a standard video conference because the video is not used to show the faces of the participants in the discussion, as with a face-to-face meeting, but is used to show the technical problem to be solved and floor passing is done by handing over the portable miniature camera.

4 User Requirements and System Functions

The observation of the problems engineers and planner/analysts encountered when they used the media space connections suggests a number of user requirements to be addressed. The following list identifies the most important user requirements and related system features to be implemented:

- *Audio quality and voice conference calls.* Users discussed and argued a lot during the connections on the shop floor. They therefore expected at least what they already get from their telephone system: reasonable audio quality and conference calls. Audio quality is a critical factor: if audio quality was too poor, the users interrupted the video/audio link. Future systems have to deliver good audio quality (at least telephone standard) and have to support multi-user conference calls.
- *Smooth transition between low resolution moving video and high resolution still pictures.* People could cope with the low resolution of moving video at 64 kbps and appreciated the interactivity of the live connection ("show me this, try that..."). However they sometimes needed more resolution to see fine details. In such cases, they were definitively ready to trade off moving images for resolution (assuming the bandwidth remained constant). The system could therefore be improved by providing a tool to pause the video and send a frame at a higher resolution. Furthermore, it would be useful to save the captured frame and sketch over it.
- *Smooth transition between stored and live video.* In some circumstances live video in not convenient. For example, sometimes it was difficult to recreate the conditions of a problem or to shoot the video and discuss with people at the other end at the same time. In these cases users prefer to be able to shoot a video first, save it and edit it off-line, then play the stored video during a live connection and discuss it, with the possibility of going back and sketching over it. From a technical point of view, this approach offers the opportunity to perform asymmetric compression of the stored video and therefore increase the resolution of the video transferred. One interesting application of this feature can be exploited if live video connections are recorded. The participants in the discussion can go back to the recorded session and watch or hear again something that happened before.
- *Sketching and annotation tool.* The packaging engineer, after using the link as described above, suggested that it would have been very useful to have "a light-pen to sketch over the video as they do in football matches on TV". As the user suggested, it is important to integrate media spaces and computing spaces. It would be useful to have a synchronous shared sketching tool to draw over video and still images, such as the TeamWorkStation system (Ishii,

1990). Furthermore, the system should be improved with an asynchronous multimedia annotation tool for editing stored video.

- *Shared virtual pin-board.* The users of the office share link often put up notices or pictures in front of the camera. However they did so only when they were not there because the message had to take over the whole video window to be readable. This desire to exchange written notes can be addressed with a computer tool that allows the two people sharing a virtual office to share a computer window where they can put up short messages and sketches, or even icons of documents that can be double-clicked. The difference between this and e-mail is that the content of the shared area is always visible on the screen, but it is not permanently stored and lives until you write something else on top of it or close the window. This would be like sharing a virtual pin-board with the colleague.

5 Summary and Conclusions

The main purpose of the study was to test the media space concepts outside of a research lab. We chose an engineering organization within a large multinational firm characterised by having product development and manufacturing distributed across many countries. We focused on a major product development project in a critical stage within its two-year life cycle. Members of the project were divided between two sites: a design centre in England and a factory in the Netherlands. After analyzing the distributed organization and work patterns, we installed two media space connections: an office share between the desktops of two people sharing administrative tasks across the two sites and a dial up video-phone between the desktop of an engineer in England and the shop floor of the factory in the Netherlands.

The office share improved the cooperation between the two planner/analysts by opening up new levels of communication at a distance: phatic communication and communication by behaviour (see section 3.1.2). The office share supported various levels of communication whose effects could be detected in the behaviour of planner/analysts and other people in the office. It created a shared awareness allowing to feel the "presence" of the remote person without demanding a focused social engagement, it maintained social relationships by reinforcing the physical and psychological contact and it delivered the information produced by people's behaviour.

The video-phone link was used to solve problems arising on the shop floor (see section 3.2.2). It was never used for face-to-face communications: people did not stay in front of the camera but always used the video to show technical problems. The visual dimension not only speeds up and eases communication, but also increases cooperative attitudes, confidence in the solution and mutual trust. This is in contrast to what users said about the existing video conference system, i.e. that it creates an adversarial relationship among the participants. We think that the attitude towards the two systems was different because the video-phone and office-share links are more integrated into the workplace, readily available and more flexible for solving specific problems and supporting informal communication. CTV is perceived as a tool used by upper management to control the status of the project minimizing travel, whereas the media space links are viewed as tools to improve the quality of work.

Users complained about the low video and audio quality available because it was below their expected standards, respectively television and telephone. Users however could cope with the low quality video when it became clear that the media space connections allowed them to acquire new degrees of freedom, to do new things that before were impossible. On the other hand, sometimes users gave up when the audio quality was too bad or when it took too long to set up a connection.

Users were very quick to adapt to the technology and its limitations. Users understood very easily that bandwidth was the bottleneck, and they were extremely good at shifting from one communication medium to another for solving the various problems they encountered: they used telephones, beepers, fax and e-mail together with the video links, using a lot of creativity and *bricolage*. However the system we provided was not flexible enough; for example, it was not possible to print a frame from the video and send it by fax, or store video on tape and transmit it later to the other site, or sketch over the video.

For media spaces to be effective in the "real world" we have to design systems that allow people to shift smoothly from one medium to another according to the problem at hand, the current situation, the various technological constraints and the resources available (e.g. bandwidth, resolution, background noise, etc.). Furthermore, the media space should be integrated with the existing communication infrastructure, which is usually very rich but very fragmented: telephones, beepers, answering machines, faxes, e-mail, etc. The user requirements that emerged are: smooth transition between live video and stored video; smooth transition between moving video and high resolution still pictures; smooth transition between multimedia links and shared computing spaces of two kinds: synchronous shared sketching over video or still images, and asynchronous message posting on a shared pin board area; smooth transition between voice two-users conversation and multi-user conference call. These requirements add new dimensions of flexibility besides the transition between focused and peripheral use of the technology originally conceived at the beginning of the project.

Acknowledgements

Special thanks to Bob Anderson, Graham Button, Ian Daniel, Richard Harper, Michel Hessoir, Ian Mair, Mike Molloy and Alistair Rogers for their contributions to the field study. We also thank all the users who cooperated with us in spite of their other commitments.

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