Bringing Media Spaces into the Real World

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Abstract

This paper describes an experiment to test the media space concepts developed at Rank Xerox EuroPARC 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; an unfocused "office share" to support administrative tasks. The results of user observation are that the video links did prove to be effective for problem solving on the shop floor, enhancing cooperation, mutual trust and confidence, and for supporting new forms of communication in the virtual shared office. We observed that users integrated very quickly the new video links into their existing media space made up of telephone, beepers, satellite video conference, fax, e-mail, answering machines, etc. Users learnt very easily 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; from two user conversation to multi-user conference call.

1 Introduction

The RAVE project at Rank Xerox EuroPARC has been exploring ways to support cooperative work using a media space infrastructure offering ubiquitous video and audio interconnectivity within a building (Buxton and Moran, 1990). RAVE did not focus on replacing face-to-face communication, but rather it explored ways to support work and social relations throughout their spectrum, from informal casual encounters to focused, formal and planned cooperative tasks (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). One of the most interesting features of RAVE is the flexibility to shift from the peripheral to the focused views of the technology: from the unobtrusive presence of a glance, to the "shared awareness" feeling of an office share in the periphery of attention, to the full engagement of a video-phone conversation.

The main purpose of the experiment described in this article was to test these media space concepts outside of our 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 in 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: a dial up video-phone between the desktop of an engineer in England and the shop floor of the factory in the Netherlands; an office share between the desktops of two people sharing administrative tasks across the two sites.

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 experiment delivers lower quality video but uses less bandwidth, making it affordable for international links. Therefore one of the aims of the experiment was to find out what are 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".

The results of the experiment are that the two types of media space connections installed did prove to be effective for supporting some tasks. The video phone link was successfully used to solve problems arising on the shop floor (see section 3.3). 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 4.2). The video links were never used to replace face-to-face communication: people did not stay in front of the cameras and used only voice for discussing. The video was used to show the detail of technical problems on the shop floor and to show a large view of the desk of the planner analysts.

Users did complain a lot about low video and audio quality available for the experiment because it was below their expected standards, respectively television and telephone. However users 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.

We observed that 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 some video on videotape and later transmit it to the other site, or sketch over the video.

What emerges from this experiment is that people in the "real world" are used to cope with poor technology and limited resources. Therefore for media spaces to be effective in the "real world" we have to design systems that allow to shift smoothly from one medium to another according to the problem at hand, the current situation, the various technological constraints, the resources available (for example bandwidth, resolution, background noise, difficulty in recreating and shooting a problem, headphones, 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. This 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.

2 Research Study

We met extensively with the director of the division, who is a key supporter of the project. He provided an overview of his organization, the current set of projects and the functions performed by different groups. He introduced us to key people and arranged for us to interview all of his senior managers and many of the second-level managers.

We began making a presentation to the managers that described the media space in our lab and our desire to identify key areas in which this technology could be applied to support their work. We interviewed 22 managers and staff members. 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 (either a project or a function) and the communication breakdowns they faced and the current strategies for addressing those breakdowns. We taped the interviews, which were later transcribed. In addition to the interviews, we attended a number of regularly-scheduled meetings, attended by people from each site either live or using satellite video conference.

At the end of this study of the organization, we identified two areas which had the highest coordination and communication needs across the two sites in England and the Netherlands: i) cooperation between design engineers and manufacturing engineers on the shop floor; ii) configuration management.

For each of these two areas we installed a particular kind of media space link across the two sites, and we observed how users took advantage of the video connections. The link on the shop floor was available for two weeks; during this period, we spent two days at each site sitting next to the equipment and observed what users did. For the remaining time, we collected videotapes of the video and audio going through the link and later interviewed the people who used the link.

The link to support configuration management ran continuously for six days spread over a period of about one month, during which we installed two different software packages. We spent a few hours observing what users did while the link was up and interviewed the users various times.

2.1 The user organization

The experiment was conducted in the product development organization of a large multinational corporation. Product development and manufacturing are distributed on a global scale: clean sheet designs are usually created in Japan and then localized for the European market by a central design organization in England, which is responsible for product development from design through to market launch. Manufacturing functions are the responsibility of another multinational division, which manages the factories. The product we analyzed is assembled in a factory in the Netherlands.

The firm is characterized by the typical pressures of high-tech companies in a highly innovative, competitive and turbulent market: increase customer satisfaction, maintain the technological edge, improve quality while decreasing costs, compete in time. Product development in particular is under great stress: reducing the time-to-market, streamlining processes, simultaneous engineering, adapting to fast technical change, 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 has a fairly sophisticated telecommunications infrastructure: 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; electronic mail; fax; satellite video conference facilities for meetings. All engineers and administrative staff have either a workstation or a computer terminal. In spite of this infrastructure, engineers have to travel a lot to the other site. Travel costs are up to 10% of the total product development budget. However at the time the field study was conducted, the travel budget was being reduced within a cost cutting program, therefore there was great attention towards tools for reducing face-to-face meetings.

3 Dial up video link between design centre in England and the shop floor in the Netherlands

This link was designed to support the complex communication and coordination tasks between design engineers in England and manufacturing engineers in the Netherlands. They have to transfer and share a large amount of knowledge because the English engineers have most of the know-how about the product design, whereas engineers in the Netherlands maintain the relations with the local suppliers (about 80% of the components are sourced in Europe to conform with EC import regulations). During the critical stages of the product development cycle large groups of engineers move from one site to the other for various weeks, and everybody agrees that this is necessary. However there is great concern about decreasing the frequency of short trips to the other site. Therefore one of the users' expectations was to use the video link for solving "small" problems arising on the shop floor which require cooperation across the two sites.

One end of the video link was set up on the desktop of a "system integration engineer" in England. The system integration function is responsible for making sure that all sub-systems of the product work together. Because of his integration role, the integration engineer knows most of the designers and was capable of inviting the relevant design specialist to solve each problem discussed over the video link. The other end of the video link was on the shop floor in the Netherlands; the equipment was installed on a trolley which could be moved around the shop floor to reach various points in the manufacturing line or in the rework area.

3.1 The technology

The system we installed provided a dial up video and audio connection between the system engineer's desktop and the trolley on the shop floor. The system was based on a couple of codecs connected by a 64 kbps data line (see figure 1). The codecs we used implement the H.261 standard and are prototypes of a low end single board model designed for desktop video conferencing using public ISDN networks, with a target market price of about 4000 pounds each. 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 experiment, therefore we had to use a switched 64 kbps IDN line. The unavailability of a standard ISDN line made the set up on the Dutch side a bit more complicated: a 64 kbps modem was connected to a X.21 controller, which was connected to the codec and to a VT100 terminal. In order to dial and disconnect the line, users in the Netherlands had to type some commands on the VT100 terminal.

On the English side of the link, we installed only 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 mike. On the Dutch side, we installed two monitors (one for incoming and one for outgoing video) and two cameras; one camera was clamped to the trolley, the other was a miniature camera (diameter 1 cm., length about 5 cm.) with a flexible cable which could be easily moved for showing small details. Using the miniature camera people in England could read 2 mm. type on the other end. On the shop floor there was a lot of background noise, therefore we used headphones with built in mike. In England we also installed a videotape recorder which captured the video coming from the Netherlands and the audio in both directions.

The system described had one main problem: it was a research prototype and therefore it was not very reliable in an industrial environment. There were a lot of concurrent 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; the system on the Dutch side was constantly moved around the shop floor.

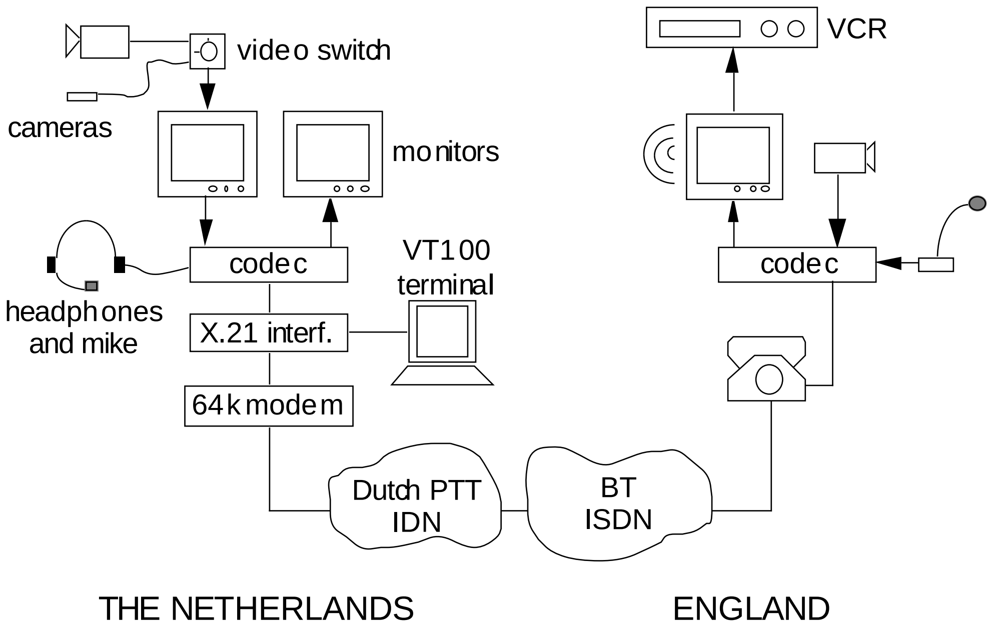

Figure 1: Configuration of the system to link the design and manufacturing engineers

3.2 User observation

During the two weeks of availability of the system, the users tried to use the link eleven times, but they could establish the video connection only six times, because of the various technical problems described above. Here are three examples of tasks carried out using the video link:

- *Packaging problem.* After a design change of a part, also the packaging for shipping had to be changed. The change involved making a new cut into the cardboard and assembling the pieces together in such a way that they would fit. Using the video link, a packaging engineer in England showed step by step how to make the cut and how to assemble the pieces, with the people in the Netherlands repeating each step at the other site. In half an hour a problem which would have required a trip was solved. 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, and eventually they found another related bug. The problem could have been described by voice on the telephone, but the reason why the manufacturing engineer asked to use the video link was that 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 was working fine on the prototypes, but did not work reliably on some units coming out of 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. Also in this case, the main problem 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 media space link provided: poor audio quality, poor video resolution, unreliable technology. However the engineers were really excited when they could solve a problem using the video link without travelling. In a critical stage of the experiment, when the video-phone system was not working because of technical problems, the manager of the manufacturing engineers said: "This technology is a pain: it never works, the resolution is much worse than we expected, the audio is impossible to use. However yesterday we used it and it saved us a trip, therefore I will let my people spend more time on it. I would rather have this lousy link than nothing. There are many things here which are not perfect and we have to cope with, this will be another one".

3.3 Results

At the end of the experiment, the user company management made an evaluation of the effectiveness of the video link and a cost/benefit analysis. They concluded that the system was useful for solving some problems on the shop floor and that during the experiment the link saved at least two trips between England and the Netherlands; however more time was spent than saved because the technology was unreliable. In the report they wrote: "when it works and is used for the right application, it is a very powerful tool".

What emerges from the experiment is that, in spite of some technical flaws, the shop floor video link did support effectively some tasks. We found that the following typical transactions are supported well by the link:

- *show a problem*: a manufacturing engineer shows something going wrong on the production line and ask the designers for explanations, solutions, changes, etc. (eg. 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. 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 ball".

- *show a solution*: a design engineer shows how to do something on the shop floor (eg. packaging problem). The video link allows to go through each step of the process and to perform it simultaneously at both sites, so as 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 also allows to see the solution working at both sites and therefore 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 (eg. 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 to replace a face-to-face meeting. The video is used to show the technical problem to be solved.

4 "Office share" between two planner analysts in England and the Netherlands

The second media space link was installed between the desks of the planner analysts in England and the Netherlands. Planner analysts are in charge of configuration management, which includes keeping track of design changes, evaluating the cost of parts and changes, maintaining the inventory of the thousands of parts which make up a product. 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 have to be submitted to the planner analyst, who registers them, evaluates their cost and submits them to the Change and Control Board (CCB). The CCB is a meeting held every Tuesday morning using a satellite video conference facility; at this meeting senior management at both sites reviews all change requests and decides whether or not to approve them.

To support the cooperation between the two planner analysts we installed an office share link, that is a continuous video connection active throughout the day (Gaver *et al.*, 1992). The idea of an office share is that a constant video connection in a small screen or window provides an unobtrusive medium to feel the "presence" of the remote person without demanding a focused 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.

4.1 Technology

In order to provide a constant video connection across countries at a reasonable cost we could not use a dial up ISDN link nor a 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 workstations with a Videopix video digitizing board running two software packages: vfctool, which comes with the Videopix board, and IVS, a public domain software developed at INRIA. (see figure 2)

Vfctool is a software designed to grab frames from a video digitizing board shared over a LAN. It is capable of grabbing video frames on one machine and display them on a remote one, but it does not do any kind of compression, therefore it produces a heavy data stream and is very sensible to network traffic. With the average traffic conditions on the TCP-IP network between England and the Netherlands, it took up to 5-6 minutes to update an image with a size of 320x240 pixels and 8 grey levels, and sometimes the software crashed. It was clear that we were using vfctool for something it had not been designed for, however it allowed us to get started.

In order 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, according to network traffic. IVS was very robust to packet loss and network overload; the only problem was that sometimes the video window was closed down, however the software never crashed and the user could restore the link with a couple of mouse clicks.

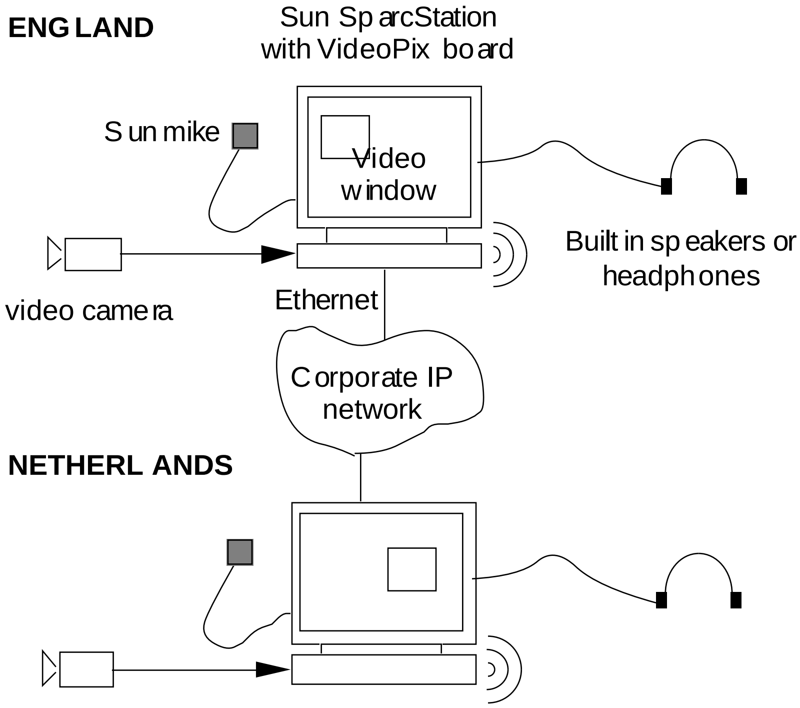

Figure 2: Configuration of the system to link the planner analysts

4.2 User observation and results

At the beginning of the experiment we installed vfctool, however it was clear that the refresh rate was too slow: it happened that 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. Therefore we switched to IVS, which offered a smaller video window with poorer quality but higher refresh rates. After the initial disappointment for the poorer video quality, the users did like the new link and kept on using it until the equipment was removed.

When we interviewed the users, they said that the major use of the IVS link was to see if the other person was at his desk or busy before calling him on the phone, which happens at least five 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 experiment concluded that there were no tangible savings from the use of the office share link; they described the link as a “nice-to-have”.

The results of the office share experiment seem to be very elusive. We need a model of communication to capture and evaluate 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 the communication open, to maintain the social relationship between the two partners, to reinforce the physical (or virtually 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 to show how the office share supports the phatic function of communication is the following. The two planner analysts particularly enjoyed the office share on Monday night, 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 at night to prepare the figures for the meeting the following morning. When the large open space offices at both sites were desert and dark after standard working hours, the two persons 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: by not being in the camera view one communicates that he or she is not available, by having a lot of paper on the desk one communicates to be very busy, by putting the feet on the desk one communicates to be relaxing, etc. All of these messages can be encoded and decoded with no effort and attention by the people sharing the virtual office; in fact in most of the cases they are not even aware that communication is taking place, and they cannot stop communicating if not 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 lay out. 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 the camera and just behave.

5 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 in future systems. Here is a list of 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, therefore they 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. Therefore 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 sometimes they needed more resolution to see fine details. In those cases they were definitively ready to trade off moving images for resolution (assuming to keep bandwidth constant). Therefore the system can 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 to go back and sketch over it. From a technical point of view, this approach offers the opportunity to perform more sophisticated batch 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 in the recorded session and watch or hear again something that happened before. This approach to meeting support is addressed in *Where Were We?* under development at Xerox PARC (Minnemann, 1992).
- *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. Furthermore, the system should be improved with an asynchronous multimedia annotation tool for editing stored video; this can be done with a general purpose tool to edit time-based media called EVA, under development at Rank Xerox EuroPARC (Mackay, 1989).

- *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 for the message to be readable it had to take over the whole video window. This desire to exchange written notes can be addressed with a computer tool which allows the two persons sharing a virtual office to have a shared 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. (see fig. 3)

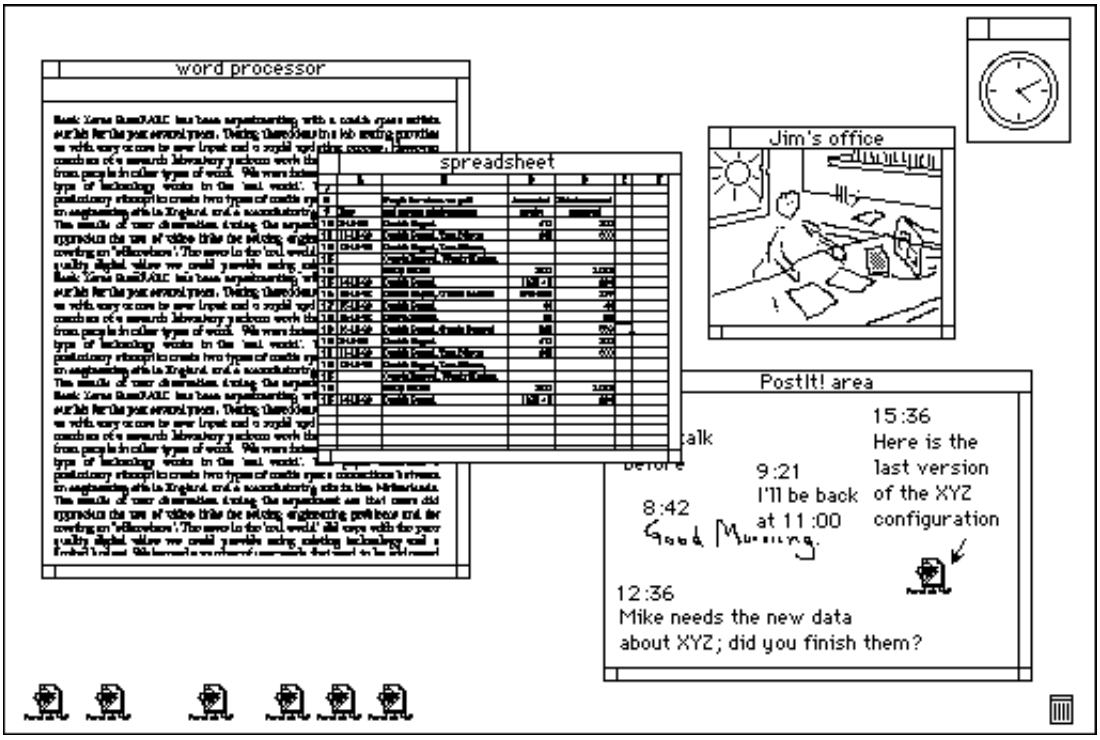

Figure 3: Office share and prototype of shared virtual pin-board

6 Conclusions

We found that the media space connection on the shop floor was very useful for engineering problem solving: the visual dimension not only speeds up and eases communication, but also increases cooperative attitudes, confidence in the solution and mutual trust. 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.

However these media space connections are useful in a “real world” setting only if they are integrated with the existing communication environment and if they are flexible enough to allow users to shift from one medium to another according to the resources available, the current technological constraints, the nature of the task to be performed. Some recommendations for the design of media spaces have been outlined.

7 Acknowledgements

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8 References

Buxton, W. and Moran, T. P. (1990). EuroPARC's integrated interactive intermedia facility (iiif): early experiences. In *Proceedings of the IFIP WG8.4 Conference on Multi-User Interfaces and Applications* (Herakleion, Crete, September 1990).

Gaver, W. W., Moran T. P., MacLean A., Lovstrand L., Dourish P., Carter K., Buxton W. (1992). Realizing a Video Environment: EuroPARC's RAVE System. In *Proceedings of CHI '92* (Monteray, California, 3-7 May, 1992). ACM, New York.

Jakobson, R. (1960). Closing statement: linguistics and poetics. In Sebeok, T. (ed.) (1960) *Style and Language.* MIT Press, Cambridge, Mass.

Mackay, W. E. (1989). EVA: An Experimental Video Annotator for Symbolic Analysis of Video Data. In *SIGCHI Bulletin* 21, 1. October 1989.

Turletti T. (1993). *H.261 Software Codec for Videoconferencing Over the Internet*. INRIA Internal Report N° XXXX. Sophia Antipolis.

Watzlawick P., Bravin J. H. and Jackson D. D. (1967). *Pragmatics of Human Communication*. Norton Publishing, New York.