Experiences in the design of the *well*, a group communication device for *teleconviviality*

Nicolas Roussel
Laboratoire de Recherche en Informatique
UMR 8623, CNRS & Université Paris-Sud XI
91405 Orsay Cedex, France
roussel@lri.fr

ABSTRACT

Over the last forty years, a number of audiovisual systems have been proposed to allow people to communicate over distance. However, although these systems have greatly improved in their ability to support formal meetings, they are still hardly usable for the informal discussions that take place before and after the meeting or during breaks. This paper presents the *well*, a group communication device that combines audio and video links with an original design to support *teleconviviality*, the emergence of a relaxed atmosphere well adapted to distributed informal communication. The *well* is not intended to replace existing video-conferencing systems, but rather to supplement them as a solution to the informal communication problem. After introducing some related work, we provide an overview of the design concept of the *well*. We then present some details about its hardware configuration and the video compositing software it uses. Finally, we discuss some lessons learned from this work and conclude with directions for future research.

Keywords

Teleconviviality, informal communication, video-conferencing, prototyping, iterative design

1. INTRODUCTION

Over the last forty years, a number of audiovisual systems have been proposed to allow people to communicate over distance. Multi-point audio and video communication has become easier and cheaper. Image and sound quality has improved a lot, making video-conferencing more and more comfortable. As an example, distant people can now be shown life-size, their voice being spatially mapped to their on-screen location. However, although video-conferencing systems have greatly improved in their ability to support formal meetings, they are still hardly usable for the informal discussions that take place before and after the meeting or during breaks.

The usual placement of the cameras, microphones, speakers and monitors used in video-conferencing systems favors a global face to face situation, opposing the local participants as a group to the other remote groups (Figure 1). This setting reinforces the mental separation between opposing factions created by the physical separation [24]. It also makes it hard for a particular participant to engage in a side conversation with one or more remote participants since they cannot be addressed individually. Hence, during breaks for example, informal discussions usually take place independently at each site, involving only the local participants of the site. This also probably explains why Halloween costume parties shouldn't be held over a video link [16].

Figure 1: Typical video-conference setting, from [22]

Yet, as Egido points out, "there is a large body of literature that suggests that it is often over informal chats outside of official meeting rooms that important information is transmitted and real decisions are made" [6]. Recognizing the importance of these spontaneous informal interactions among co-located people working together, a number of research labs have proposed systems such as Media Spaces [12] that are specifically designed to support them over time and distance.

Media Spaces and similar research projects are specifically tailored to a particular group of people through long term use and iterative refinement. Video-conferencing systems, on the other hand, are available to users in a "one size fits all" philosophy. In a way, these two classes of systems differ from each other like "haute couture" and "prêt à porter". Coincidently, whereas Media Spaces hardly made their way out of research labs, video-conferencing systems are indeed used everyday to support pre-arranged, formal interactions. They even became more popular recently, as travel safety concerns increased.

In this paper, we present the *well*, a communication device that combines audio and video links to support informal interactions between small distributed groups of people. The *well* is not intended to replace existing video-conferencing systems. It is rather meant to supplement them as a solution to the informal communication problem. The rest of the paper is organized as follows.

After introducing some related work, we provide an overview of the design concept of the *well*. We then present some details about its hardware configuration and the video compositing software it uses. Finally, we discuss some lessons learned from this work and conclude with directions for future research.

2. RELATED WORK

VideoWindow [7] is one of the first group communication systems specifically designed for informal communication. Based on a high aspect-ratio video channel with full-duplex audio, it was able to display life-size images of people in a distant room, as seen through a virtual window. A three month trial between two commons areas concluded that the system indeed provided a sense of shared space and that communication occurred in a quite natural manner. However, the authors admitted that "even when all of the factors outlined are accounted for, we believe that the current VideoWindow system lacks something due to factors we do not understand". One problem they outlined was that the commutative properties of face-to-face interaction (i.e. I can see/hear you if you can see/hear me) are not preserved by the technology of the system. Another problem was that even with life sized images, the psychological distance to someone at the other end of the system is greater than that in a comparable face-to-face situation.

Media Spaces were originally designed to model the informal types of communication that occur in hallways and in commons areas, re-establishing the possibility of informal communication for people located apart from each other [12]. Since the early work at Xerox PARC [2] and EuroPARC [23] and the similar Cruiser [3] system of BellCore, a number of other systems have been developed to support a wider range of informal interactions [13, 5, 21, 17]. These systems showed in particular that high-fidelity is not necessary when the goal is not to replicate face-to-face reality but rather to provide opportunities for informal communication. However, most of them were designed as an audio and video environment accessible from individual workplaces and not as a group communication device.

Other systems were designed after a glass pane metaphor similar to the one of VideoWindow. VideoWhiteboard [20] and ClearBoard [10], for example, use this metaphor to support shared drawing, gesture-based communication and gaze awareness between distant users. However, these systems were primarily aimed at close collaboration and not informal communication. Moreover, they were both originally designed for two users on two sites, although the size of their display surface allows one or two other persons to join a collaborative session.

Instead of a glass pane, a number of other systems have used a mirror metaphor to create seductive and pleasant-to-use interfaces. Videoplace [11], for example, combined the silhouette of participants with interactive graphics projected on a wall. Talking about user reactions to this system, Krueger et al. say [11]: "When people see their image displayed with a graphic object, they feel a universal and irresistible desire to reach out and touch it". This fascination for self-image was also used by Fleischmann et al. in Liquid Views [9]. This interactive installation combined a horizontal display showing the image of the participant with a touch-screen that allowed him to disturb the display as if it was a liquid surface. Part of the concept of this project was to "arouse the observer's curiosity and seduce him" [8]. Likewise, Darrell et al. relate a similar curiosity reaction to their Mass Hallucinations [4] prototype, a virtual mirror that distorts participants' face in real-time.

HyperMirror [15] is a group communication system that relies on the mirror metaphor: it shows the images of local as well as remote participants on a single screen, making them believe they are all in one room and looking at themselves in a mirror. Although this system does not try to reproduce face-to-face reality – as opposed to VideoWindow, VideoWhiteboard or ClearBoard – it proved to be an efficient means of communication and was qualified as "natural" and "pleasant to use" by its users. In particular, experiments showed that the display of self-reflection helped reduce the psychological distance between the viewer and the other participants.

The glass pane metaphor provides a sense of shared space, supports gesture-based communication and possibly gaze awareness. VideoWindow, VideoWhiteboard and ClearBoard were designed after this metaphor as point-to-point communication devices. As mentioned in [10] however, extending them to connect three or more sites would require a major change in the metaphor itself. The mirror metaphor offers an interesting potential to attract people to a video-based system and invite them to interact with it. As demonstrated by HyperMirror, it also helps reduce the psychological distance between local and remote participants when combined with the glass pane metaphor.

In this section, we have described a number of technologies and systems that go beyond traditional video-conferencing systems to support richer forms of interactions. Yet, none of these technologies and systems are able to support informal interactions to the level of what we can easily experience in co-located situations, as illustrated by Figure 2. In the next section, we will present the *well*, our solution to that problem.

Figure 2: Convivial atmosphere leading to multiple informal conversations

3. THE WELL: OVERVIEW AND CONCEPT

Most traditional video communication systems rely on the assumption that the interactions between local and remote people should be channeled though a single communication device shared by all the local participants. We believe that this unique communication focus that makes traditional systems perfectly suitable for formal meetings is precisely what makes them inappropriate for informal discussions before and after the meeting, or during breaks. We think that one of the keys to supporting informal communication in these contexts is the ability for people to move away from the formal focus of the meeting and to gather in smaller informal groups, as illustrated by Figure 2.

Therefore, in addition to the traditional video-conferencing equipment, we propose to provide users with several other group communication devices allowing sub-groups of local participants to communicate with similar sub-groups from other sites. Together with other more subjective elements such as humor or fun, we expect that these multiple communication foci will contribute to support *teleconviviality*, that is, the emergence of a relaxed and joyful atmosphere well adapted to distributed informal communication.

The *well*[1] [1] is our first attempt towards a group communication device specifically designed to support teleconviviality. This design was guided by the idea that we wanted to attract a small group of co-located people to an audiovisual device that would allow them to communicate informally with other distant people using similar devices. The *well* looks similar to a high table, ideally oval or circular (Figure 3). Its video communication system consists of a set of cameras and a horizontal display, placed on top of the table. The display shows a graphical composition of the local cameras and those of the other remotely connected *well*s. The audio communication system consists of a set of microphones and speakers that create a spatialized auditory scene consistent with the graphical display.

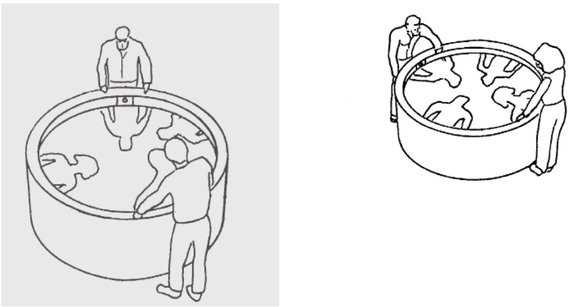

Figure 3: An artistic view of the *well*

The height of the *well* invites people to stand around it and bend over its curb to look at the display and chat with co-located as well as remote people. The cameras, microphones and speakers are placed so that one must be seen by a camera and heard by a microphone to be able to see the display and hear something. This is a key point of the design: it makes the *well* more natural to use as well as it simplifies the image and sound capture.

The horizontal display has a number of advantages. People need to get to the *well* to fully understand what it is. Although this might sound like a disadvantage, we anticipate that curiosity will draw people to the device, as it did for installations like Videoplace, Liquid Views and Mass Hallucinations. Since the camera images are being displayed on a horizontal surface, there is no common notion of *up* or *down*. Thus, the images can be laid out in a circle, facing the local users like reflections in water. Observations of users of Videoplace and HyperMirror have shown that people naturally tend to change their position so their own image doesn't interfere too much with other participants. We anticipate that a similar social protocol will apply and that users will gather in a circle around the *well*, as we usually do when discussing informally.

4. PROTOTYPING THE WELL

Two *well* prototypes have been built (Figure 4). in this section, we describe the hardware configuration of these prototypes as well as the video compositing software that we created for them.

[1] en français, le *puits*

Figure 4: The two prototypes and a close-up

4.1 Hardware Configuration

In order to simplify the design, the two prototypes are rectangular rather than circular. A video projector and a mirror are placed inside each *well*, the image being back-projected onto an etched-glass tabletop (Figure 5). Three speakers and three thumb-size analog video cameras are placed inside its curbs, around the display. Three spotlights ensure appropriate lighting conditions inside the field of view of the cameras. The spotlights are fixed on three metal handles that converge over the center of the tabletop. Three directive cardioid microphones hang over the display from this point, far enough from the speakers to reduce acoustic coupling and avoid echo and feedback effects. In addition, the inside walls of the prototypes are covered with acoustic absorbing material.

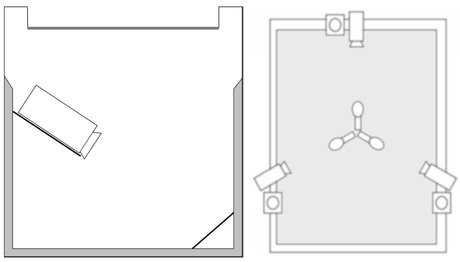

Figure 5: Hardware configuration: the side view shows the projector, and the mirror; the top view shows the three cameras, the three microphones and the three speakers

The sound spatialization effect is best perceived when participants are not too close to one of the speakers. For this reason, the three handles are fixed close to the speakers and the cameras are pointed between them, two microphones covering the field of view of each camera. Thus, in addition to sustaining the microphones, the handles incite participants to move to the best locations for seeing, hearing as well as being seen and heard.

Audio signals are transmitted on analog cables, each microphone being connected to a single speaker. The three cameras of each prototype are connected to a quad composer that makes a single analog video stream out of them. This video stream is transmitted on an analog cable to an SGI O2 workstation close to the other *well*. A custom video compositing software running on the O2 extracts the three original images from the analog quad stream, recomposes them and sends the resulting image as a second analog video stream to the video projector inside the *well*.

In order to be able to display the local camera images as well as the remote ones sent over the analog cable, a third video stream is necessary. Unfortunately, the O2 workstations can not handle more than two analog video streams at the same time. To overcome this limitation, we used an additional IP link between the two O2 workstations. This data connection allows the compositing software to send back a digital copy of the quad stream images received on the analog cable. In the current implementation, these images are JPEG-encoded and transmitted using the UDP protocol and a best-effort strategy. As a result, images from the local cameras are displayed with a little time lag. However, this time lag doesn't affect the communication between the two sites since it applies only to the local images.

Figure 6 summarizes the audio, video and data connections between the two prototypes.

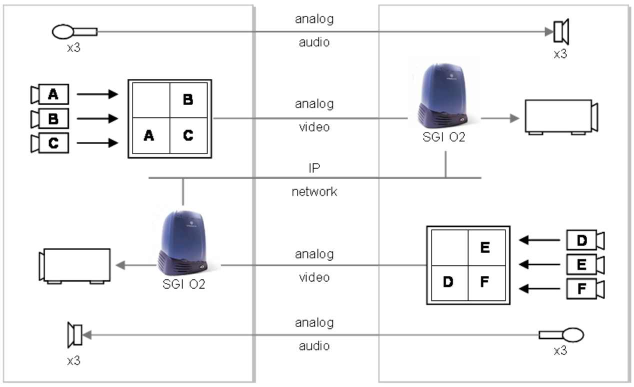

Figure 6: Audio and video setup

4.2 Video Compositing Software

Previous work on video communication systems have proposed various techniques to compose the images of local and remote participants. ClearBoard, for example, uses a translucent overlay of local and remote images. One configuration of HyperMirror uses a video chroma-keyer to extract the images of participants standing in front of a blue curtain and superimpose them over the image of another location. As always, each of these techniques has its own advantages and drawbacks. Translucent overlay, for example, usually results in a loss of luminosity and chroma-keying techniques require control over the background.

Our video compositing software uses the videoSpace toolkit [18] to manage the analog and digital video streams and OpenGL to compose them. The current compositing process uses a translucent overlay of the images. However, before drawing the images, a transparency mask is applied (Figure 7) to remove uninteresting parts such as the corners in order to reduce the overlapping regions and thus the loss of luminosity in the composition.

Considering the three images taken from the cameras of a *well* as illustrated by Figure 8, two types of placement can be used to combine these images so as to preserve the mutual orientation of the participants:

The first placement is based on the mirror metaphor: each image is flipped horizontally and displayed with its base oriented towards the curb of the *well* (Figure 9). This placement should be the more natural one since people hardly ever see themselves face to face except in mirrors. In fact, during HyperMirror experiments, Morikawa and Maesako indeed observed that people move more naturally when they see their reflection [15]. However, since the images are mirrored, remote participants will not be able to read any text material presented to one of the cameras.

Figure 7: Applying a transparency mask on a typical image

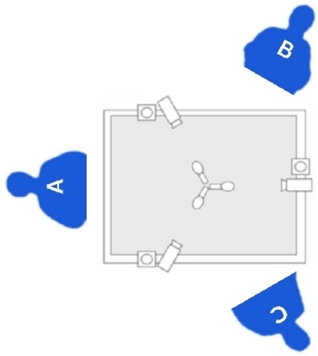

Figure 8: Sample situation involving three participants

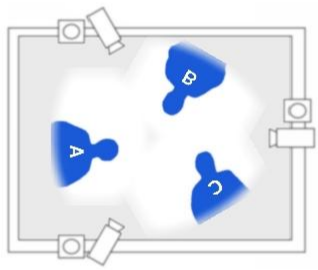

Figure 9: Mirror composition of the images of Figure 8 as it would appear in the other *well*

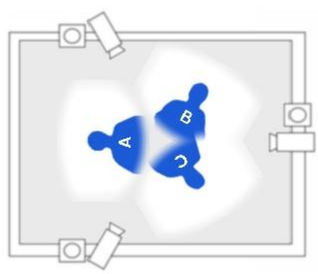

Figure 10: Glass pane composition of the images of Figure 8 as it would appear in the other *well*

The second placement is based on the glass pane metaphor. The images are not mirrored but displayed as-is. However, in order to preserve the mutual orientation, they must be displayed with their base oriented towards the center of the *well* (Figure 10). This placement should presumably be more confusing to the users because of the lack of a similar experience in the real world: not only the image of the participants is not mirrored, but the image closest to them appears upside down. Yet, in this configuration, text documents are readable, which can be interesting to broaden the kinds of interactions between the local and remote participants.

Figure 11 shows the result of the composition and placement settings of Figures 9 and 10 on actual images taken from one of the prototypes.

Figure 11: Compositions using actual images from a *well*

Figures 12 shows how the two placements can be used to display local participants' images (labelled D, E and F) in addition to remote ones (A, B and C).

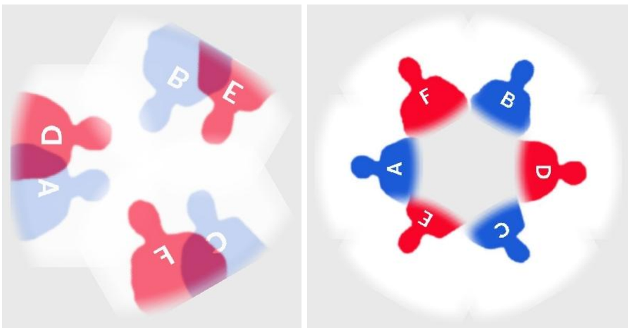

Figure 12: Compositions showing local and remote participants

The current implementation of our video compositing software takes a configuration file as an argument. This file describes one or more video sources to be used and the compositing process to apply to the images. Figure 13 shows a sample configuration file that produces mirror compositions similar to the left image of Figure 12:

- The first line declares a video source. In this case, the source is the analog video input of the O2 workstation, showing the quad composition of the three remote cameras.
- The second line requests images from the analog source to be digitally forwarded to the other *well* using the `vsmp` protocol of videoSpace.
- The three `subSource` commands describe the position of the camera images within the video stream and the transparency mask and geometrical transformations to apply to them.
- The second `source` command declares a second video source. This one corresponds to the local camera images sent back over the IP link by the other *well*.
- The next three `subSource` commands describe the place and shape of the local camera images in the global composition.

```
source videoin:/anydev/analog
srcForward vsmp://other-well:8989

subSource A 0 0 1 1
  subScale      0.5
  subRotate     -90.0
  subTranslate  -0.2 0.0
  subMask       file:masks/miroir-transparent.jpg
  subFlip
subSource B 0 0 1 1
  subScale      0.5
  subRotate     150.0
  subTranslate  0.1 0.173205080757
  subMask       file:masks/miroir-transparent.jpg
  subFlip
subSource C 0 0 1 1
  subScale      0.5
  subRotate     30.0
  subTranslate  0.1 -0.173205080757
  subMask       file:masks/miroir-transparent.jpg
  subFlip

source vsmp://localhost:8989

subSource D 0 0 1 1
  subScale      0.5
  subRotate     -90.0
  subTranslate  -0.2 0.0
  subMask       file:masks/miroir-transparent.jpg
  subFlip
subSource E 0 0 1 1
  subScale      0.5
  subRotate     150.0
  subTranslate  0.1 0.173205080757
  subMask       file:masks/miroir-transparent.jpg
  subFlip
subSource F 0 0 1 1
  subScale      0.5
  subRotate     30.0
  subTranslate  0.1 -0.173205080757
  subMask       file:masks/miroir-transparent.jpg
  subFlip
```

Figure 13: Sample configuration file

Depending on the resolution used when digitizing analog video streams (full-size PAL, half-size or third-size), the video compositing software typically achieved display rates between 10 and 25 frames per second for remote images and 5 to 15 frames per second for local ones.

5. DISCUSSION

Preliminary informal user testing shows that the *well* is very well received. As anticipated, people are attracted to it and are able to communicate with the remote participants spontaneously, without training. Observations met our original expectations about the emergence of a sense of teleconviviality. The prototypes also helped us to understand the importance of some unanticipated factors, such as lighting conditions or the nature of the background.

One interesting property of the *well* is that the number of sites and the number of participants at each site do not change the nature of the interaction with the device. As we explained, the use of a horizontal display allows to distribute the participants around it.

This should make the *well* more scalable than vertical display systems such as VideoWindow, ClearBoard or HyperMirror. By simply augmenting the size of the display and possibly the number of cameras, speakers and microphones, it should be possible to connect more than two sites. The size of the display could be augmented, for example, by installing the *well* on a platform allowing a greater distance between the projector and the mirror. The *well* could also be made circular, and stools or armrests could be added to make it more comfortable to use.

Prototyping has been recognized as an efficient means of developing interactive applications for some time [19]: iterative design promotes the refinement and optimization of the envisioned interaction techniques through discussion, exploration, testing and iterative revision. The design of the *well* indeed required several iterations from the initial sketches to fully functional prototypes. However, this prototyping was much harder than we anticipated. In particular, even with modern hardware and software, digitizing six video sources in real-time to compose them and produce two new analog images remains a challenge.

Specific analog video hardware such as the quad composer helps create high-fidelity prototypes and focus on the interactions between the users and the system rather than the technology required to implement them. But this kind of hardware is still expensive and sometimes hard to setup and maintain. Moreover, high-fidelity prototyping is not good for identifying conceptual approaches unless the alternatives have already been narrowed down to two or three, or sometimes even one [19]. Low-fidelity prototypes have proved useful to narrow these alternatives. But then again, what level of software support do we have to prototype innovative video applications?

As we were designing and prototyping the *well*, we developed our own video toolkit, videoSpace [18]. The Mash streaming media toolkit [14] and some other platforms developed by the Multimedia and Network research communities offer high-level video digitizing and transmission services. However, these platforms naturally tend to focus on technical issues and usually rely on the idea that images are to be transmitted or displayed as-is, as big and as fast as possible. Although this conception is well suited to applications such as video-on-demand and traditional video-conferencing, it is too restrictive for more innovative applications such as the *well* that might involve image processing or composition of multiple sources in real-time.

Our work is motivated by the desire to focus on the *uses* of video, rather than the *technologies* it requires. In this perspective, the videoSpace toolkit is not focused on performance or reliability issues, but rather on the ability to support rapid prototyping and incremental development of video applications. VideoSpace allowed us, for example, to develop the video compositing software of the *well* several hundred kilometers away from the place where the hardware parts were actually assembled. Pre-recorded video streams showing a rough view of what the cameras would see were used to experiment with different composition methods even before the first prototype was built. Network sources were later used to simulate the analog video cables between two prototypes. A software mosaic composer was also used to simulate its analog equivalent when it was decided to use such a device to put all the cameras of a prototype on a single video stream. In addition to supporting rapid prototyping of the software and simulation of various hardware configurations, videoSpace allowed us to develop the software required for the *well* on a laptop running Linux and to later recompile it without a single modification and run it on the SGI O2s.

6. CONCLUSION AND FUTURE WORK

We have introduced a novel device for remote informal communication based on a horizontal display and a spatialized sound system that support a consistent audiovisual scene between local and remote sites. Informal evaluations of this device are promising and open the way to new research. We plan to continue this work by experimenting other designs for the *well* including shared interaction through digital and physical objects to complement communication and enhance teleconviviality.

We strongly believe the Multimedia research community would benefit from a wider perspective on the design, prototyping and development of innovative applications of audio and video. We think that the *well* is a good representative of these potential applications and hope that this example will contribute to the evolution of existing middleware platforms towards more flexibility.

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