Designing for Distributed Scientific Collaboration: a Case Study in an Animal Health Laboratory

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Abstract

We have been exploring the design of an advanced collaboration platform to support scientists in a national animal health laboratory to work collaboratively across a physical containment barrier. This paper describes the design considerations based on the findings from a field study of the collaboration processes in this particular environment. We emphasize the need of providing flexible support for various information sharing practices. The major component of the platform – a collaboration environment which integrates life-size video conferencing and a large shared digital workspace - has been under routine use. Our preliminary results from a user study of the distributed group meetings supported by the platform have shown the value of high quality audio-video communication in combination with the feature of allowing access and simultaneously sharing multiple data resources.

1. Introduction

Scientific work usually involves collaboration between scientists from different teams who work around specific resources and equipment. Physical distance between different teams has been one of the obstacles to scientific collaboration. Computer supported cooperative systems have been increasingly used to assist distributed scientists to work with each other, share facilities and databases without regard to geographical location [8, 19]. These systems and their usages have been widely explored in various scientific applications [e.g. 10, 15, 19], and have demonstrated the potential to enhance distributed scientific collaboration [e.g. 1, 6, 8, 9, 12, 14].

Design of collaboration systems to support scientific collaborations has been largely explored from the perspective of building large scale cyberinfrastructure [e.g. 1, 4, 15, 19]. However, the user experience of distributed teamwork and the design of effective interaction technologies are essential parts of the exploration of supporting distributed scientific collaboration [9, 12, 16]. The design of specific communication and shared interaction components of a scientific collaboration system are still challenging in the research of Human Computer Interaction and Computer Supported Cooperative Work.

Supporting distributed scientific collaboration needs to address not only audio-video communication between scientists but also their collaborative analysis of information from various scientific resources [19]. Advances in video conferencing technologies have improved users’ communication experience in distributed meetings. High quality audio and video as well as the physical design of system have been able to create a face-to-face collocated impression for the users [e.g. 11]. In parallel to this, research in shared digital space and multi-display environment has addressed data-driven collaborations, including scientific collaborations [e.g. 3, 23]. Prior work, including our previous research, has demonstrated research prototypes which integrate shared digital space and video-mediated communication space to support distributed hands-on collaborations [e.g. 5, 18, 20]. One of our research interests based on these work has been the design of these technologies in real-world settings. Our investigations also include how to provide principles and new ways of supporting distributed teams involved in collaborative activities such as scientific analysis.

Evaluations of scientific collaboration systems have shown that the success of remote scientific collaboration relies on judicious system design [19]. However, there is still a challenge in understanding the design strategies to support distributed scientific collaboration which usually entails different level of interaction needs [7]. Supporting collaboration between distributed teams requires appropriate technologies tailored to the teams’ environment to achieve the teams’ functions. An understanding of users’ work practice and collaboration can influence the adoption of technologies and long-term outcome [12, 22]. Our past experience of developing advanced
ICT solutions to support distributed collaborations in challenging environments, such as hospital critical care [13, 21] has shown the importance of this design approach. The evaluations of these systems have shown that the consideration of dynamic interaction patterns, tailored design and good communication media quality are the key success factors and contribute to the effectiveness of a collaboration system that can be integrated into the work environment.

This paper describes our research into designing a scientific collaboration platform to support distributed collaboration in a unique and challenging environment - the Australian Animal Health Laboratory (AAHL). Our work contributes to the research field of scientific collaboration systems and technologies with a case of designing collaboration technology in a scientific laboratory environment. The iterative design process and the details of the technical design have been reported in [17]. This paper focuses on design considerations which are part of the systematic design components. The understanding of the collaboration processes within AAHL based on a field study will be presented. Following this, the design considerations around these processes will be described. Finally the preliminary results of the user studies after the initial deployment of the platform will be described.

2. Background

The scientific collaboration we have investigated is in the Australian Animal Health Laboratory which is a national centre in disease diagnosis, research and policy advice in animal health. AAHL provides expertise in developing the most sensitive, accurate and timely diagnostic tests to assist the eradication campaign in the event of a disease outbreak. AAHL also undertakes research to develop new diagnostic tests, vaccines and treatments for animal diseases of national importance.

AAHL is one of the most sophisticated laboratories in the world for the safe handling and containment of infectious microorganisms. Its high biocontainment facility allows it to safely handle a range of animal species to physical containment level three (PC3) and the highest level, PC4. These facilities are fully enclosed large work areas and separated from the general office area with a range of airlock doors. There are strict biosecurity rules in this working environment. For example, staff must take a compulsory shower to exit from the biocontainment area; equipment leaving this area needs to be decontaminated; scientists need to wear personal protective equipment, such as standard laboratory clothing in PC3 and fully encapsulated plastics suits in PC4.

This “secure” environment poses a challenge in terms of effective, rapid communication and data sharing for scientists working at different physical areas. Real-time interactions and sharing scientific data between different groups of scientists are critical for AAHL to provide diagnostics and research services, particularly in the context of the time pressure of an emergency disease outbreak. AAHL management has proposed a range of e-Research activities in integrating advanced ICT capabilities for diagnosis and research work. Among these initiatives is a collaboration platform to enhance the communication and collaborative work within AAHL.

This has led to the Biosecurity Collaboration Platform project which aims to develop a platform to support scientists to effectively communicate and share information across the containment barrier. Our design team and design representatives from AAHL have worked closely over a one-year design and development process. At the time of writing the major component of the platform, a shared workspace, has been installed at AAHL and under routine use.

3. Understanding the collaboration

A field study was conducted as an initial step of the design process. The study was undertaken by two design team members over a period of two months. We tried to build a picture of users’ particular work environment and collaboration practice. The study method combined semi-structured interviews with focus group meeting and site investigations. The focus group meeting involved twenty scientists and was held at the beginning of the study. The purpose was to introduce the design team’s research and design plan to AAHL staff and to prompt discussions around potential scenarios and design ideas. Eleven interviews were conducted at the interview participants’ work areas. Interview participants were from different work groups and were asked about their work responsibilities, their interactions with other groups and communication difficulties encountered. Visits to PC3 were important to help the design team to understand the particular physical setting as well as resources and artefact arrangements. We were not able to enter PC4 due to an extra level of biosecurity in PC4. Our understanding of the work practice in the containment area and technical solutions described in this paper are limited to that of PC3 only. Based on transcription of the interview recordings and site visit notes, the analysis of the field study particularly focused on the information sharing process for different work situations. These
understandings led to the design strategies that guided the platform development.

3.1. Partly distributed collaboration

The staff in AAHL are organised into major programs or projects they are working in. In terms of work capability, there are three major work groups in AAHL: the diagnostics group which includes the diagnostics management team and the diagnostics scientists; the research group; the microscopy group which provides microscopy services for related diagnostics and research work.

The group organization is not determined by the containment barrier but rather depends on the nature of work carried out by the group (Figure 1): diagnostics scientists, microscope scientists and some of the research scientists need to spend most of their work time for experiments and tests using instruments in the containment areas; the diagnostics management team who undertakes diagnostics case analysis works in the general office area; some of the research scientists do not require the containment facility for their work and most of their work is based at the general office area; some of the team or program leaders need to spend time to engage with the hands-on work inside and maintain the management work from outside. There are individual computers in the general office area for all the staff including those spend most of the time inside the containment area. Staff in the containment area use instrument computers for specific tests or use common computers in the reading rooms in PC3 for accessing stored data or other general purposes.

Different groups in different work areas collaborate with each other in their diagnostics and research work. For example diagnostics work involves diagnostics scientists, diagnostics management team and microscopy scientists. The sample sent from a client is tested by diagnostics scientists and examined by microscope scientists in PC3. These scientists then hold a group meeting with the diagnostics management team (e.g. the veterinary officers) to discuss these results. Finally the diagnostics management team analyzes these results in combination with the case detail and generates reports to the client. It is important for the diagnostics management team, diagnostics scientists and microscope scientists to effectively share information in order to deliver timely diagnostics services particularly when there is an animal disease outbreak. Similarly the research work in AAHL often involves collaboration between research scientists on both sides of the containment areas, microscopy scientists and diagnostics scientists in PC3 and requires efficient data sharing between these scientists.

In contrast to the traditional classification of “same place” and “different place” collaborations [2], the collaborations in this environment can be considered as a mixture of collocated and “distributed” due to the fact that the teams work at different sides of the containment barrier but are within one social organization and one physical building. The effort required to pass through the containment barrier introduces communication difficulties between scientists working inside and outside of the containment areas. Email and telephone are the common communication tools for scientists on different sides of the containment area. Quite often, staff has to spend time going through the containment barrier to have a face-to-face discussion.

Figure 1. Overview of the work groups (in circles), their work areas and the ways of communication and information sharing between groups in AAHL.

3.2. Communication and information sharing process

Work in AAHL often involves information sharing between scientists from different groups and from different sides of the containment areas. There are different processes of communication and information sharing in terms of number of participants involved, formality of the process and data resources involved (see Figure 1):

- **Group discussion.** This involves scientists from different groups or from different work areas to get together to share understanding of the data and results, for example the regularly diagnostics meeting as we described. Participants usually bring printout of related documents. This is usually organized beforehand and held in the general office area.
• **Ad-hoc individual discussion.** This can be a quick individual discussion through email or telephone when there is a question to ask. Staff may send the data via email before the discussion, or refer to stored data in repositories that both of them can access.

• **Discussion of evolving data.** This is the discussion around evolving data, such as sample slide images under microscope or images from culture plates. This process involves scientists working on the instruments inside PC3 and a couple of other scientists, for example the team leaders who work partly outside. Involved scientists need to coordinate their on-going work in order to meet in PC3 at the right time.

We have seen that the containment barrier introduces communication difficulties between scientists working in different physical areas. Further investigation of the collaboration practice between different groups has revealed that communication inefficiencies are caused by not only the containment barrier, but also the difficulties of sharing information between different work groups and the lack of support for the information sharing process, including the inadequate support for group discussion meetings, the lack of mutual access to data resources and lack of remote access to evolving data.

**Inadequate support for group discussion meetings:** Scientific collaboration meetings are different from other meetings such as business board meetings in terms of the type of data material and amount of data involved in the data sharing process. Various sources of data and information need to be available to be reviewed and interpreted by different discipline scientists at the same time. Furthermore scientific group discussions usually require simultaneous viewing of multiple documents rather than the sequential display of single document like the normal PowerPoint presentations in face-to-face meetings.

**Lack of shared access to data resources:** Each work group has its own data repositories which can usually be accessed only by own group members due to the necessary data access configurations. During the ad-hoc telephone discussion, scientists from the same group and working in different areas might be able to refer to stored data in data repositories that both of them can access. For the scientists from different groups, data has to be sent via email before the ad-hoc telephone discussions or face-to-face discussions.

The current common shared repositories do not include image or graph data involved in the discussions. There are shared data repositories available, such as the Lab Information Management System (LIMS) which records the text-based diagnostics test results and reports. However images, such as scanned and digital microscopy images are stored in databases which can only be accessed by the microscopy group members. Without a shared view on the image data details, the telephone communication can lead to conversational inefficiency.

**Lack of remote access to evolving data:** The discussion of hands-on experiment or test is a particular component of scientific work practice in AAHL. For example, a microscopy scientist inside PC3 might need to show real-time images from fresh samples under a microscope to consult an expert microscope scientist; or they may want to show interesting findings to research scientists who need microscopy results to direct their research directions. The opportunity for other scientists to share a microscopy scientist’s view of the images of a fresh sample is lost when a scientist outside the containment area is not able to go inside in time. Another example is that in a face-to-face meeting scientists may require access to data that is not readily accessible on a data server, such as the data being processed on individual computers or instrumental computers. While they can organize a meeting later to have a discussion based on stored microscopy images or other data, there is a need to improve the efficiency and work flow by support the sharing of real-time information.

4. **Design considerations**

The understanding of the collaboration issues has driven our design solution which has focused on improving information sharing processes at various requirement levels. In this section we first give an overview of the collaboration platform. We then describe the design considerations which integrate insights from the field study into the specific design, particularly in the design of the shared workspace which is the major component of the platform.

![Figure 2. Schematic diagram of the collaboration platform structure at AAHL](image)
There are two shared workspaces installed: one in the PC3 area, and one outside the containment area, in the general office space (Figure 2). Each installation will provide a collaboration work space that is connected to the AAHL network and linked to a number of computers through the network. These computers include predetermined individual computers both within and outside the containment area and dedicated computers associated with instrument (e.g., microscope) in PC3. The individual computers and instrument computers linked to the platform are predetermined by the AAHL management. The platform allows scientists to share information and communicate with each other from various work areas.

4.1. Flexible support for various information sharing processes

The findings from the field study have revealed different levels of requirements in information sharing practices. Our design solution addresses issues in each type of the interaction processes. Due to the mixed nature of these collaborations, we do not treat these individual interaction components as separated functionalities.

As a result, our technical solution to the setting is a flexible platform which uses integrated communication and shared digital workspaces over the AAHL network to allow information sharing from individual computers, instrument computers and the shared workspaces we have installed [17]. It enables different uses of the platform: 1) “distributed” group meetings through the two “shared workspace”; 2) ad-hoc discussion in a way that scientists can remain in their individual desk; 3) discussion of evolving and real-time data from individual computers or facilities. The actual uses of platform may consist of a combination of these components and allow the spontaneous shift from one component to another.

- **Group discussion.** The two shared workspaces support the need to enable a group of scientists in PC3 to communicate and share data with a group of scientists in the general office area. Through the shared workspaces, scientists can take part in a high quality video conferencing with remote colleagues and can access various data repositories as required as well as the desktops of linked computers which run specific applications that need to be shared with all meeting participants. The two shared workspaces are located in meeting rooms and shared by different groups.

- **Ad-hoc individual discussion.** This is to support individual scientist using their individual computer to share information and communicate with other scientists. The AAHL IT Support team who manages the IT infrastructure and services has worked closely with our design team and has investigated ways to support this information sharing process. To date the scientists use the two shared workspace for this type of interaction.

- **Discussion of evolving data.** The platform supports scientists in PC3 to share real-time image information from their workstations with staff working in the general office area. Currently scientists sitting at the “shared workspace” outside the containment area can interact with the shared microscopy images and the associated application windows. The solutions for access from individual personal computers and suitable audio-video communications for these situations are being explored.

4.2. Integrated communication and collaboration spaces

Scientific collaborations focus on not only sharing data and but also collaborative analysis which quite often involves conversations in meetings. This implies that there are two aspects to support distributed scientific collaboration: a shared digital space and a video-mediated communication space. Studies have explored the appropriated design of these spaces from user experience perspective [3, 18, 20, 23]. One of our key design foci has been the appropriate integration of these two aspects. Different collaboration scenarios might require different design solutions. Here we describe our design consideration of the shared workspace which targets on the support for distributed group meetings. Figure 3 shows the shared workspace at AAHL. The picture was taken when the shared workspace was tested by the design team members in the containment area during the initial trial period.

![Shared workspace in the general office area at AAHL](image-url)
The shared workspace has four large displays and allows a group of scientists to share information and have video conferencing with their colleagues at the other side of the barrier. Through the shared workspace, scientists can access various data resources, such as databases and data from server computers, desktops, computers which run specific applications (e.g., microscope), real-time animal monitoring videos and animal telemetry data from the facility in PC3 area.

The shared workspace supports high quality concurrent information visualization of multiple data sources and real-time interaction with shared application windows for participants at each side. An 8.3 million pixel display space (four times a full HD resolution) workspace can be shared and displayed across the sites.

Two video cameras are placed in their functional positions and two microphones are placed on the table at each side. The dual HD video link between the two shared workspace and high quality echo-cancelation enable a natural face-to-face communications.

Our design focused not only on the technical solutions of communication and application sharing, but also the appropriate configuration and flexible control of the video space and information space on the displays. Users can select the video to be shown in a small picture-in-picture mode so that the four displays are used for data visualization when they engage in data sharing and analysis activities; or they can select to show the video on the bottom two screens for a high quality video conferencing conversation.

4.3. Minimal change to the work practice

As described we were intent on not changing different groups’ existing practices. The overall functionality of the platform respects existing needs of collaboration. Furthermore, on the technical level, the platform does not introduce significantly new software to manage access to data repositories and specific applications. For example, although the shared workspace can bring together access to and specific applications of predetermined computers, the use of the shared workspace does not affect the software interfaces of the existing applications on these computers, such as the computers of microscopes which are expensive and sensitive instruments. Similarly, it will not change the access interface to data repositories.

4.4. Security concern

The platform is used by the staff at AAHL and it needs to comply with existing data security configurations. For example, from the shared workspace the access to various data repositories is consistent with individuals’ data access security rules. In order to control the access and security, the computers to be linked to the system are defined and assessed by the AAHL design representatives and our design team.

5. User studies

We conducted the post-deployment study in two stages. The first user study was conducted after the two-month trial at AAHL to understand the early usage of the shared workspace and provide feedback on the area-for-improvement. The second one is being conducted after the platform has been implemented for eleven months in order to find long-term usage trend and difficulties which may require particular intervention. These two studies have been undertaken by one design team member who is also one of the researchers conducted the field study before the design. The second user study is ongoing at the time of writing. In this paper we focus on preliminary results which reflect some of our design considerations.

5.1. Early stage of the technology deployment

In the first user study we adopted a mixed method approach which included questionnaire, interview and observation. Data collected also included records in the BCP log book and meeting room booking information in the Microsoft Outlook calendar.

21 staff from diagnostics, research and microscopy groups took part in the study. This was around 50% of the total number of regular or potential platform users. These participants were identified as staff who have used the shared workspace. 16 of them completed the questionnaire. 5 formal interview participants were asked about the same questions in the questionnaire and other questions to have in-depth understanding of their experience.

5.1.1. Overall usage. The participants had an average use of 2.71 times during the first two months after training sessions at the beginning of the implementation. The analysis of the questionnaires reveals that usually during the meetings there were 3-4 users at each side. The meetings lasted around 50 minutes. Most of the meetings (50%) were planned regular group meetings but also some ad hoc and special purpose meetings.

5.1.2. Distributed group meeting. Since the shared workspace is designed to support group meeting, we were interested to understand how the distributed
group meeting compare with the face-to-face group meeting before the use of the platform. The ability of accessing, sharing and interacting with multiple data resources and high quality audio and video have been highlighted by study participants, as one of the research scientist commented:

“Large space to work in and large presence of the people you are working with. The ability to multi-session so that you can real-time access to all the data you need to discuss. Often when running a standard video conference it is difficult to see the data in PowerPoint and if you realise that a different set of graphs or other image files etc would be valuable, they are not there. With this system they are! This is a must for all groups that use videoconferencing on a regular basis.”

We asked about the usefulness and helpfulness of the platform compared to face-to-face meetings on a five-point scale rating question (1: much worse, 3: the same, and 5: much better). Interestingly, 6 out of 20 participants reported that the distributed meeting was the same as the face-to-face meeting and 6 out of 20 participants actually felt that it was better than the face-to-face meeting. The participants explained that this was because of the availability of various data resources and shared interactions of the visual information. 8 out of 20 participants felt that distributed meeting was worse than the face-to-face meeting. From the explanations of these participants this could be interpreted as that face-to-face being necessary for better engagement with people if getting in/out of the containment area was not considered as an issue for them.

5.1.3. Flexible configuration. Our findings showed that 40.9% of the participants found that the choice of display mode depended on the situation during the meeting. It is also interesting to see this difference across different work groups. Full screen mode was more popular than the small mode in the diagnostics groups while this was the opposite in the microscopy group. These findings reflect the design consideration of supporting different group and different type of interaction processes (e.g. conversational meetings or data-centred meetings) and the solution of a flexible configuration of display spaces.

5.1.4. Modifications. There were technical issues reported when the participants answered the question of “what do you do not like about BCP, suggestions?” Some of these issues were due to the limitation of the platform and some of them were related to users’ familiarity with the platform. Based on the feedback received in this user study the design team has added several features to the shared workspace. For example being able to work on documents on a private workspace before sharing them on the displays was mentioned as an area for improvement by some of the staff who used BCP from outside the containment area. As a result, an additional laptop linked to the platform has been used at the room outside the containment area. Another example related to the fact that the shared workspace was installed at common meeting rooms. To avoid unnecessary disturbance to other meetings, we added a feature in the user control interface that the video connection can only be set up when the remote end user has also logged on (his/her ID appears).

5.2. Later stage of the deployment

The data from the second user study being conducted at this time includes a computer generated log showing the use of the shared workspace as well as interviews. The computer log was introduced after the system updates were completed. It records the time of use, the IDs of staff who log on, display mode selected and computer resources accessed. Interviews were used to gather feedback regarding the technology benefit and difficulties that scientists have experienced after using it for almost a year. A comprehensive analysis of these two studies results including the long-term adoption and benefit of the platform will be addressed in our future publications.

6. Discussion and future work

The design of collaborative technology for supporting scientific collaboration relates to the research field that associates collaboration technologies with scientific collaboration [8]. Behaviours and interactions of collaborations in workplace, particularly information sharing practices in complex work environments, are different to those in controlled settings where these technologies are often originally designed. It is necessary to understand and support the communication mechanism and the dynamic of information exchange in these real-world collaborations. We have described our contextual understanding of the work practices at AAHL and the design strategies which contribute to the design of a scientific collaboration system to support this particular “distributed” scientific collaboration. Our work extends related research of collaboration technologies to an application of systematic design, implementation and evaluation of the technologies in a complex work environment.

The work complexity within this ‘secure’ scientific laboratory environment is mainly due to the existence of a containment barrier. It is also due to the need for data sharing and the shared understanding of these data across different groups. This data-driven requirement
and the difficulty of information sharing between different groups can also be found in other scientific collaboration practices. The complexity also includes the need for linking people with various instruments and facilities [8, 15]. This need for real-time scientific collaboration around instruments is one of the core capabilities for technology to support [8].

We have identified a set of principles to guide the design of a collaboration system that supports various scientific interaction processes at AAHL. To address the complexity of scientific collaboration, the design must be flexible enough to support different forms of collaboration practices and an appropriate configuration of the solutions. The collaboration system will also need to work across different work groups, support their specific requirements and comply with their existing data security rules. Furthermore, a staged design and development process that involves the end users as well as the organizations’ management will ensure that the system is introduced and integrated smoothly into their work practice.

Collaboration technologies have been increasingly used within various scientific domains. It is important to explore the diverse situations in scientific collaborations to understand the implications they have to the design of these technologies in different contexts. We hope our design considerations in this case study can be applied or adapted to other similar challenges in designing distributed scientific collaborations.

Our user studies in distributed group meetings supported by the shared workspace have shown the value of allowing access and sharing of multiple data resources simultaneously, as well as the feature of high quality video conferencing. A complete understanding of the actual usage as well as the effectiveness of the platform will be enriched by our continuous work in the user study being conducted. Future work will also include the design of integrated audio-video communication and information sharing facilities to support the ad-hoc individual discussion and real-time data collaboration. The implementation of the existing shared workspace opens up opportunities for potential broader collaboration applications, including the support for PC4 work, as well as the collaboration between AAHL and its key research partners. A multi-site cross organization collaboration platform using similar technologies is being investigated by our design team.

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8. References


