Towards a Collaborative System for Delivery of Remote Mine Services

Craig James[1], Weidong Huang[2], Kazys Stepanas[1], Eleonora Widzyk-Capehart[1], Leila Alem[1], Chris Gunn[1], Matt Adcock[1], Kerstin Haustein[1]

[1]CSIRO, Australia; [2]University of Tasmania, Australia

{craig.a.james, kazys.stepanas, eleonora.widzyk-capehart, leila.alem, chris.gunn, matt.adcock, kerstin.haustein}@csiro.au; tony.huang@utas.edu.au

***Abstract*—While work has been done to support remote collaboration, and many remote access products exist, these efforts often need stable connections and high bandwidths, or have a mix of functionality, poor security, or complicated set up processes. There is no singular piece of remote collaboration technology suitable for the remote delivery of high-quality planning and scheduling services to clients at a mining site. To fill this gap, a remote mining engineer (RME) concept has been proposed and a functional requirements analysis has been conducted. Based on the identified requirements, a further study was performed to characterise existing technologies and identify the scope for future work. We report on the method and findings of this study in this paper. The main contribution is the identification of a suitable collaboration tool for developing RME.**

Keywords-Remote collaboration; Remote expert services; Tele-operation; Screen sharing; Remote mining engineer

I. Introduction

Mining companies (service requestors) employ engineers for critical roles in on-site planning and operations, but access to skilled staff willing to work in remote locations is difficult [7]. Mining engineering firms (service providers) can retain top-level personnel in metropolitan areas but they require frequent trips to remote mining locations to maintain effective communication with service requestors. This results in high travel burdens and service costs, and lengthy, inefficient exchanges over email or phone calls to ensure the services requested are delivered.

Individually, remote communication technologies such as tele-conferencing, Skype, desktop sharing, telephony, and email services do not address the following key challenges in the open cut mining environment:

- Quality of service – effective remote communication relies on clear reception of as many cues as possible (text, tone, gesture, facial expressions).
- Low bandwidth – broadband communications in remote areas is still very poor.
- High security – need to protect integrity of data and control systems where downtime from malicious intrusions can introduce high production penalties
- Usability – available remote technologies are difficult to set up, configure and maintain.

There is a body of work in the areas of tele-assistance/tele-collaboration to improve collaboration between personnel in remote and metropolitan areas (e.g., [2][3][8][9][11]). However, much of this work involves the use of bandwidth or display formats unsuitable for mines [10].

A Remote Mining Engineer (RME) concept has been investigated in the literature [1]. Based on this work, we intended to develop a RME system with the following objectives:

- Facilitate collaboration between staff inside the service provider and between staff of the service provider and the service requester.
- Reduce the need for staff of the service provider to be present remotely without compromising the quality of services provided.

This system would combine existing (text, voice, visualisation and data sharing) and innovative communication technologies (tele-presence, tele-collaboration, tele-assistance, and immersive environments) to improve collaboration and communication over long distances between on-site and off-site personnel. More specifically the system will rely on the following technologies:

- Tele-presence to enable a sense of physical presence with remote personnel.
- Collaborative workspaces to share manipulation of notes and sketches.
- Communication technologies (video and audio).
- Visualisation technology to share 2D and 3D data.

In the remainder of this paper, we briefly introduce the work done for the requirements analysis first in Section 2. We then present the method in Section 3 and results of our research in Section 4. Finally the paper concludes with a summary and future work in Section 5.

II. Background

Remote service delivery is becoming increasingly popular in modern business activities. This is mainly due to the requirements of reducing operational cost and increasing production efficiency. In this section, we briefly review the background information of our study.

A. Model of Remote Service Delivery

Previous studies revealed that service providers often follow a common business model to deliver remote mine services to their clients (e.g., [1]), illustrated in Figure 1.

A business case is started by a request from the client. This activates a range of work routines by the service provider, such as project initiation, site visit, internal task assignment, task progress report and check-up, task collaboration and discussion, document exchange and task re-assignment. Depending on the request context, the service can be executed by one or more personnel either collocated or in different locations. Communication methods include: face-to-face, video, audio, text messaging, emails, and data sharing via physical media.

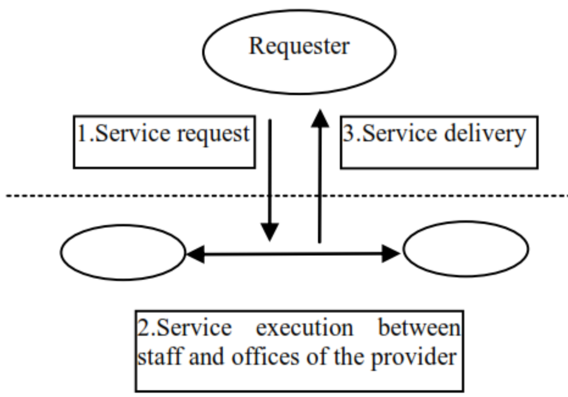

Figure 1. Business model.

B. Requirement Analysis

Observation-based user experience design methods were combined with scenario-based software design techniques for requirement analysis. Meetings were conducted with the client manager to understand high-level expectations and identify typical work procedures and scenarios [6]. On-site observations were made of how work is actually carried out by engineers, followed by focus group and individual interviews to elicit and analyse user needs.

C. Key Requirements

The results of our requirement analysis highlighted three key challenges in developing a remote collaboration system, namely:

- Bandwidth limitations.
- Security concerns.
- Usability issues.

Seven user cases were identified as key requirements when implementing a solution for delivering effective services remotely. These user cases are:

- Communicate through text, audio and video.
- Send contact requests and also accept / reject.
- Manage the system and user configuration.
- Share full screens or application windows.
- Manage different parts of the collaboration tool over different screens.
- Share electronic whiteboards and annotate.
- Transfer data over the network.

III. Research Method

Based on the requirements obtained, it was decided to make most use of existing technologies for the RME design and development. A scoping study was conducted to identify the best suitable technologies to inform the design of the RME system.

There are a large number of tele-collaboration products on the market that offer a range of services that had the potential to meet some of the requirements for delivering services to remote clients.

A broad product survey of 56 candidates was conducted. These candidates were then further examined to provide a recommendation on an initial system satisfying some of the requirements, and highlighting scope for extensions or replacements needed to satisfy all of the requirements.

The scoping study narrowed the list down to eight, which were then tested against more prominent limitations and user cases required. This resulted in two candidates that satisfied some of the limitations and user cases required.

Adobe's Connect Pro [4] and Cisco's WebEx [5] were the final two. Connect Pro was felt to be more suitable as it was more stable and handled 3D content better. A summary of this process follows in the next section.

IV. Results

Using the research method described in the previous section, we adopted a three-step process for our study: broad review, narrow review and user-case testing. These steps are presented in detail as follows.

A. Broad Review

The first step was to survey collaboration tools, deciding on the best one usable for mining engineers to work remotely. A list of 56 possible products was complied.

With the wide variety of products it was necessary to narrow the key collaboration features that would be needed. These features, in order of importance, were:

- Audio communication.
- Sharing of application snapshots.
- Annotation over application snapshots.
- Sharing of 3D applications (using OpenGL).
- Sharing control of applications.
- Video of participants.
- Ability to transfer files.
- Recording.
- Having a tool to schedule meetings.

Many products were also eliminated in this phase because they did not have sufficient security facilities, or could not deal with network firewalls.

B. Narrow Review

This list of products was reduced to eight, based on the product documentation. The products in this shortlist,

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included: JoinMe, YuuGuu, MeetingPlace, GoToMeeting, Mikogo, TeamViewer, Connect Pro, and WebEx. These products were then installed and tested.

The first five were eliminated because they did not have appropriate audio and/or video facilities. The sixth was eliminated because it had problems with annotation over OpenGL.

C. Use-case Testing

The remaining two products, Connect Pro [4] and WebEx [5] were investigated in more detail with a full set of test cases based on the user requirements. It was found that these products were very close in features offered. The main difference was in the way they responded when annotation modes were selected:

- In Connect Pro, participants drew on a static snapshot of an application (see Figure 2).
- In WebEx, participants could annotate on a dynamic view of an application (2D or 3D).

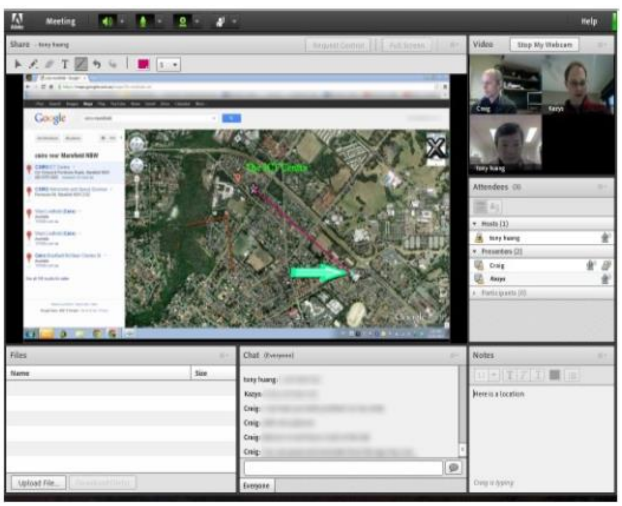

Figure 2. Connect Pro used for sharing and annotation.

The second approach seemed more powerful, allowing for indicators, such as animating lines or pointers, to continue operating in a scene. However, the live annotation feature in WebEx was sometimes unreliable with 3D applications, having annotations disappearing in many situations, lending a preference to Connect Pro's approach.

D. Bandwidth Testing

Connect Pro was then tested against reduced bandwidth conditions. For this test, a bandwidth-throttling program was installed at one end of a high-bandwidth network to simulate low-bandwidth conditions.

It was assumed that reliable audio communication was essential for any collaboration, so this was taken as a measure of usability. If the audio became unusable, the condition failed. Tests were repeated for different combinations of features, to find the minimum bandwidth that sustained features while still permitting bi-directional audio. The results are shown in Table 1. As can be seen from this table, for all features to be functional, the minimum bandwidth is 400 Kbits/s.

Google Earth was used as the shared application, as it uses OpenGL for its 3D rendering. During the tests, audio was considered unusable if parts of the audio stream were missing or if latency was so large that conversations were not possible. It was observed that as the bandwidth was limited, the audio latency would increase. This may be due to packet retransmission within the TCP/IP communications mechanism. During two-hours of the bandwidth testing session the overall upload and download data transfer was greater than 1 Gigabyte each way. This may illustrate that the overall throughput allowance must be fairly high regardless of bandwidth.

TABLE I. BANDWIDTH TEST RESULTS

Bandwidth (Kbits/s)	Audio	Video	Sharing	Annotation	Experience[1]
100	Y	N	N	N	Poor
150	Y	N	N	N	Good
200	Y	N	Y (low)[2]	Y	Good
250	Y	N	N	Y	Good
300	Y	Y	N	N	Good
350	Y	N	Y (low)[2]	Y	Ok
400	Y	Y	Y (low)[2]	Y	Ok
450	Y	N	Y (high)[3]	Y	Good
525	Y	Y	Y (high)[3]	Y	Good

1 – Subjective experience rating; poor, Ok, good.
2 – Low refresh frequency OpenGL application (Qt sample).
3 – High refresh frequency OpenGL application (Google Earth).

It should be noted that Connect Pro did not automatically detect bandwidth and adjust any features. These had to be turned on and off by users.

E. Results Summary

Connect Pro was chosen for the more explicit and stable approach of sharing and annotating over an application. This approach also left the presenter with the ability to interact with other windows on the desktop when annotation was enabled.

V. SUMMARY AND FUTURE WORK

In this paper, we have presented our approach towards the design and implementation of the RME system. This approach makes use of the existing the technologies for knowledge development and for system design. First, 56 candidates were compiled and compared based on their functionalities and application requirements. This resulted in 8 products being identified for further testing in a simulated mining office environment. In the end, Connect Pro was the winner that was considered to be the best suitable system to meet our specific user needs and to inform the design and implementation of the RME system. We are currently working on possible new functions in addition to what was available in Connect Pro.

For future work, we plan to start the full system development life cycle based on the identified user requirements and design recommendations. It is hoped that end users will be fully involved in the process and their needs will be fully addressed whenever possible. We also plan to experiment and incorporate some additional technologies into the RME system. These include augmented reality, remote gestures, remote fault diagnosis and virtual presence.

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