ErmdClime: Enabling Real-time Multimedia Discussion for Collaborative Learning in Mobile Environment*

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ABSTRACT

With the aid of mobile technology, it's possible to carry out collaborative learning (CL) in any places at any time. And the most essential and effective way to achieve this goal is through real-time multimedia discussion. In this paper, a multi-agent system, *ErmdClime,* is designed and implemented to enable real-time multimedia discussion for collaborative learning in mobile environment. The real-time bi-directional audio/video interaction and shared white board are integrated seamlessly into the system for learners with mobile devices. Besides, this system enables both local and remote learners to control the play of PowerPoint slides by voice command when discussing and annotate on the shared white board. Context-aware technology is used to switch real video and white board display on mobile devices. User study demonstrates that learners feel quite natural and highly efficient when they are engaged in the CL with mobile devices in our system.

1. INTRODUCTION

Mobile technology has been developing rapidly and mobile devices such as PDA, Smart Phone have been experiencing a significant growth recently, whose impact on people's life as well as education methodology is enormous. Roschelle pointed out in [5] that wireless Internet-based learning devices (WILD) could be used for computer-supported collaborative learning (CSCL) where the teacher becomes a guide or coach and learners take the initiative in their learning. With the aid of mobile technology, people can engage in collaborative learning in any places at any time.

Okamoto has proposed a standardization of collaborative learning (CL) in [6] based on several essential structural elements such as CL environment expression, collaborative workspace expression, CL resources expression and so on. This paper mainly focuses on collaborative workspace expression, more specifically on how to realize real-time multimedia discussion for CL in mobile environment. Because we believe that it's the most essential and effective way to carry out CL in mobile environment by real-time multimedia discussion. However, due to the limitation of memory storage, CPU power, screen size and network bandwidth of mobile devices, multimedia discussion will face great challenges in the following aspects: process and transmission of multimedia data will cost much CPU power and network bandwidth; the small screen of mobile device makes the design of the user interface very different from that on PC; various multimedia applications should be integrated into the system seamlessly to make the learners feel comfortable to use them.

In this paper, a multi-agent based system *ErmdClime* is designed and implemented to enable real-time multimedia discussion for CL in mobile environment. The challenges presented above are carefully considered and successfully overcome. A natural and user-friendly interactive way is provided by our system and its high efficiency is proved in user study.

The rest of the paper is organized as follows: section 2 introduces the related works; then the structure of the system is explained in section 3. Section 4 presents the multimedia interactions in our system and how CL is supported. We show the user study results in section 5. Section 6 concludes the paper and outlines the future work.

2. RELATED WORKS

There are many pervious works engaging in the e-learning in mobile environment, such as the EU m-learning project, EU MOBIlearn project, the ULO project of Kinjo Gakuin University in Japan and so on.

In [1], which is part of the EU MOBIlearn project, Virtual Reality (VR) and multimedia technologies are employed to provide a CL environment. Learning contents are delivered to learners' mobile devices by shared whiteboards. Learners communicate by means of voice and text chat and can direct their avatars to make gestures. However, it can't support learners' interactions on shared whiteboard, such as annotation, which may prevent the learners from fully expressing their ideas when they discuss about the learning contents. In addition, the learners are represented by avatars in the virtual room. Although

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avatars can make gestures by the instruction of learners, they are not as intuitionistic as the real video of the learners.

Another research is called ConcertStudeo [2] by IPSI in Darmstadt, Germany. It provides tools for interactions such as brainstorming, voting by wirelessly connecting PDAs with an electronic blackboard. There're no multimedia (such as audio, video) interactions provided for remote learners, thus only the local learners could benefit from ConcertStudeo.

There are some other representative works such as Multimedia Tour (MMT) in UK museum [8], the collaborative learning tool 'mediaBoard' [9] and so on.

Compared with above researches, our system has its own characteristics: firstly, all kinds of multimedia applications are integrated seamlessly. Real-time audio, video, shared white board are all supported and well organized. Secondly, multi-modality and nature interactions are especially emphasized. Therefore, in addition to the above multimedia applications, our system enables learners to control the play of PowerPoint by voice command when they discuss and annotate on the shared white board. Thirdly, context-awareness is a striking feature of this system.

3. SYSTEM STRUCTURE BASED ON SMART PLATFORM

Since various multimedia modules for mobile collaborative learning must be coordinated and integrated seamlessly, the software infrastructure, which provides the runtime environment, common services as well as the development interfaces for these modules, plays a key role. The Smart Platform, a multi-agent platform which has been used in our Smart Classroom [3] project, now is augmented to support mobile devices in our current research and is adopted as the software infrastructure for *ErmdClime*. The structure of our system based on it is illustrated in Figure 1.

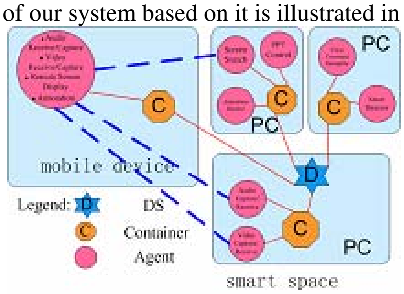


Fig. 1. The structure of ErmdClime based on Smart Platform

When CL is carried out, the communication happens between the remote students' mobile devices and the smart space where the teacher is in. Each participating computer (including PC in smart space and remote mobile device) that makes up Smart Platform hosts a Container component, which provides a local runtime environment for agents residing on that host. Globally, a DS (Directory Service) component is responsible for agent registration, message dispatch and system management. The agents with distinct functionalities run on Smart Platform and collaborate with each other. In particular, in smart space, there are audio capture/receive agent, video capture/receive agent, screen snatch agent, annotation receive agent, PPT control agent, voice command recognize agent and smart director agent; and on each mobile device, there is a remote agent into which various interactive functionalities are integrated.

The thin straight line in the figure stands for the message-oriented communication and the messages between agents are dispatched by Container and DS. The dashed line stands for the stream-oriented communication. For real-time requirement, the stream data such as video, audio, etc. are transmitted directly between agents. Note that the agents in smart space may distribute on more than three computers. Here we just draw three to illustrate the system's structure.

4. COLLABORATIVE LEARNING WITH MOBILE DEVICES

In this section, we firstly present various multimedia interactions between mobile devices and smart space, then present how to carry out CL based on them.

4.1. Multimedia Interactions between Mobile Devices and Smart Space

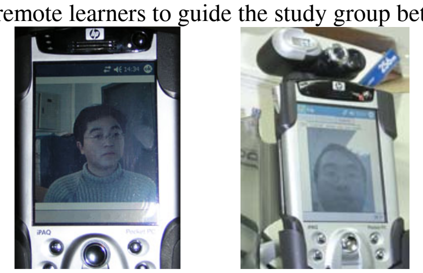
To support mobile CL, the following types of multimedia interactions are designed. Currently the mobile device supported in our system is PDA and it communicates with smart space by WLAN protocol 802.11b or BlueTooth.

Real-time bi-directional audio and video interaction

On one hand, when the teacher gives some directions to the learners, the Audio Capture Agent in smart space captures his/her voice and transmits it to remote PDAs. The remote learners with PDAs then can hear the teacher's voice. On the other hand, the remote learners are allowed to speak when they get the speaking authority. With the aid of PDAs, their voices are firstly captured, sent to the Audio Receive Agent in smart space and finally played out by the stereo; in turn the played-out voices are captured together with the teacher's and sent out to other remote learners.

In this way, the bi-directional audio interaction not only enables the remote learners with PDAs to hear the voice of the teacher but also make them capable of discussing with each other, which is crucial for CL.

Similar to the bi-directional audio interaction, by means of the bi-directional video interaction, the remote learners are able to use PDAs to browse the real video of the teacher and transmit their own videos to the classroom by PDAs with cameras when they are speaking. In turn, their videos are displayed on the Interactive Wall in the classroom. Compared with avatars that represent users in [1], real video can make the users feel more natural and intuitionistic. In particular, bi-directional video interaction makes it possible for the teacher to perceive the status of the remote learners to guide the study group better.



(a) (b)

Fig. 2. The bi-directional video interaction. (a) The teacher's video is shown on remote learners' PDA; (b) The remote learner uses PDA to capture and send his own video to smart space. This figure shows the preview on the learner's PDA.

However, it faces great challenges to transmit real video from/to mobile devices due to the limitations described in previous sections. Some methods are proposed to cope with the challenges, such as the use of codec with high compression ratio; frame rate being kept as low as possible with the precondition that the quality of the video is well guaranteed; making the video interaction optional to the users; and the most important is the network strategy: when there're some errors occurring to a frame, we just discard it instead of retransmitting it; and when a frame arrives late, we don't wait for it but just regard it as a frame with error. This simple but useful strategy is very effective, for it helps to reduce the extra network cost.

Remote white board share and control

Another important multimedia interaction to support CL is white board share and control. The remote learners, who use PDAs to share the white board of the classroom, can get the learning contents displayed on the white board in a natural way as the local learners. Figure 3 illustrates how they share the white board.

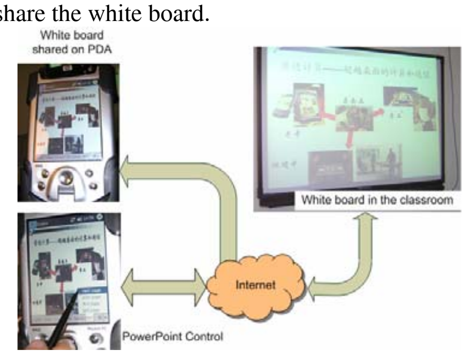


Fig. 3. White board shared on mobile devices and remote user controls the play of PowerPoint

However, PDA has a limited screen area, typically 240×320 while the screen of the PC is much larger, typically 1024×768. If the whole screen of the white board is zoomed to fit the size of PDA, the user can have a overview of the entire remote screen but the image on PDA is much smaller than its original size, preventing the user from clearly watching the content; on the contrary, if an area with the size equal to PDA's is captured from the remote screen and delivered to PDA, the user can see a clear image but it's just part of the white board. To cope with this problem, we have proposed a method in [7] to get a tradeoff between image clarity and viewport's size.

Moreover, if the content of the white board is PowerPoint (PPT) slides, our system enables the remote learners to control the play of PPT (page down, page up, last page, first page, etc.): users' commands are sent to the PPT Control Agent, then it invokes the COM interface of PPT to execute the command. Two controlling ways are supported—one is menu control (e.g. click on the "next page" menu item) as is shown in Figure 3, and the other is voice command control where a voice recognition product "ViaVoice" of IBM is used. Obviously, the control of the play of PPT when discussing is specially beneficial for the remote learners, for they no longer need the teacher to help them control the PPT, which makes the learners feel more convenient.

User annotation

During the discussion, the learners usually want to annotate on the shared white board to express their ideas more fully besides speaking. Thus, our system provides the remote users the ability to annotate on the white board displayed by their mobile devices. After coordinate transformation, the annotations are displayed on the white board of the classroom. In turn, they could be captured and sent out by Screen Snatch Agent and hence be seen by other remote learners. Different colors are automatically assigned to different users' annotations to identify them.

Smart Director

It is well known that the screen of PDA is small, typically 240×320. Therefore, it's impossible to display the real video of the teacher and the shared white board simultaneously on it. In addition to permitting the user to choose one from them to display by hand, our system could automatically switch between them according to the special context and task. There exists a context aware module in the Smart Platform, and the Smart Director Agent can make use of the context information provided by this module. Currently two types of context information are considered by Smart Director Agent: one is the duration a PPT slide lasts. If it exceeds some pre-defined threshold, a switch to real video of the teacher is triggered. The other is the event that a new PPT slide starts to be displayed, which will switch on the PPT displayed on mobile devices. With the aid of Smart Director, the learners can pay more attention to CL without worrying about which to see.

4.2. Real-time Multimedia Discussion for Collaborative Learning in Mobile Environment

With the above multimedia interactive methodologies seamlessly integrated, our system could easily make real-time multimedia discussion for CL feasible. In a typical CL scenario, there are two kinds of interactions: learner-teacher interaction and learner-learner interaction [4]. In our system, bi-directional audio and video interactions enable the learner-teacher interaction to be carried out smoothly; in the meanwhile, bi-directional audio interaction, white board share & control and user annotation technologies make the learner-learner interaction carried out in a free and natural way. And Smart Director, which automatically switches on the videos for the learners, makes them pay more attention to CL without worrying about which to see.

5. USER STUDY

Since whether our system is effective for collaborative learning and convenient to use is largely a subjective issue, the method we employ for evaluation is a user study.

24 volunteers, some of whom are graduate students and others are undergraduate students, are engaged in the user study as remote learners and are divided into four study groups with six volunteers in each group. Each group is given different subject to carry out collaborative learning. We select four different subjects because we believe that CL on subjects of different styles will have different features in their summaries. The volunteers are required to evaluate 1) the multimedia applications according to the following aspects: stabilization, whether easy to use, whether useful to CL; 2) the whole system according to whether the modules are well coordinated; whether they find it natural and convenient to learn in our system; whether the user interface is friendly and whether the system is suitable for CL. The results of the user study are summarized in table 1.

From the table below, we can see that the majority of the 24 volunteers mark our system good or acceptable and their estimations on individual multimedia applications are also positive. From the result, we find that the estimation for Smart Director is not as good as others—15 volunteers thought it's good or acceptable and others gave a relatively low score. The reason is that volunteers have different preferences for the timeout threshold a PPT slide lasts, from 5s to 30s. And most of them hope that the threshold can change flexibly according to the importance and complexity of a slide.

Table 1. (a) Summaries of user estimations on multimedia applications

Parameters	Good	Acceptable	Medium	Not Acceptable	Poor
Audio Interaction	70.8%	4.2%	8.3%	8.3%	8.3%
Video Interaction	75.0%	8.3%	4.2%	8.3%	4.2%
White board	83.3%	8.3%	4.2%	0%	4.2%
User Annotation	79.2%	12.5%	0%	4.2%	4.2%
Smart Director	37.5%	25.0%	16.7%	12.5%	8.3%

(b) Summaries of user estimations on the whole system

Parameters	Good	Acceptable	Medium	Not Acceptable	Poor
Modules-well-coordinated	91.7%	4.2%	4.2%	0%	0%
Natural and convenient	79.2%	8.3%	4.2%	0%	8.3%
Friendly UI	83.3%	4.2%	8.3%	4.2%	0%
Suitable for collaborative learning	79.2%	8.3%	4.2%	4.2%	4.2%

At the same time, they advise us to ask some middle-school students who are not so familiar with computers to carry out the user study so that the result will be more objective.

6. CONCLUSION

In this paper, we design and implement a multi-agent system based on Smart Platform, into which a variety of multimedia interaction technologies are seamlessly integrated. User study shows that our system enables the remote users conveniently and naturally to carry out real-time multimedia discussion for collaborative learning in mobile environment. Future work will continue in two aspects: firstly, we will improve the strategy for Smart Director according to the user study. Secondly, since the Smart Classroom project has been successfully used in the School of Continuing Education, Tsinghua University; in the next step, we plan to track and pilot the use of *ErmdClime* project in this school to support CL in mobile environment.

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