Smart Classroom: Enhancing Collaborative Learning Using Pervasive Computing Technology

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Abstract

Smart Classroom facilitates collaborative learning among college students. Students in such an environment form small groups to solve a specific problem or develop a group project. In a Smart Classroom, each student has a situation-aware PDA. Students' PDAs dynamically form mobile ad hoc networks for group meetings. Each PDA monitors its situation (locations of PDAs, noise, light, and mobility) and uses situation to trigger communication activity among the students and the instructor for group discussion and automatic distribution of presentation materials. Middleware can effectively address the situation-awareness and ad hoc group communication for pervasive computing by providing development and runtime support to the application software. We have developed a Reconfigurable Context-Sensitive Middleware (RCSM) for such purposes. In this paper, the characteristics of Smart Classroom, how RCSM can be used to develop such an environment and greatly enhance collaborative learning will be presented. The smart classroom will be used for a senior group software engineering project course as an illustrative example.

Keywords: Smart Classroom, collaborative learning, pervasive computing, situation-awareness, and Reconfigurable Context-Sensitive Middleware (RCSM).

1 Introduction

Over the years, technology has been used to improve the quality of instruction. However, effective use of technology to enhance the quality of teaching is a very challenging problem. Technology can be used to improve the quality of teaching in many ways. For example, it can improve the interactions between the instructor and the students, or in-group collaboration among the students.

Pervasive (or ubiquitous) computing technology makes the actual computing and communication essentially transparent to the users [1,2]. This transparency, although only partially possible in the current state of art, important to allow easier and seamless interaction of computers with humans. A pervasive computing environment is a collection of embedded, wearable, and handheld devices wirelessly connected, possibly to fixed network infrastructures such as the Internet. The two major characteristics of pervasive computing are: situation-awareness and ad hoc group communications [3-6]. Situation-awareness is the capability of a device to determine "What's going on?" in its surroundings. On the other hand, multiple devices can use their ad hoc group communication capabilities to dynamically form networks, which may facilitate different types of collaborative computing.

Although there exist some systems to improve classroom learning, using various emerging computing and communication technology [8-14], only a few have addressed collaborative learning among students [8,11]. For example, in Interactive Classroom, the students share a virtual whiteboard, electronic textbook, and the World Wide Web over a networked environment to actively participate in-class discussions [8]. On the other hand, projects that use pervasive computing technology have so far mainly focused on facilitating the note- or exam-taking or student-tracking applications in a classroom. For example, Smart Kindergarten uses sensor data collected from children or toys to make a record for the instructor to review children's activities and track their learning progress [12]. Classroom 2000 captures classroom context (teaching material or student notes) to automatically generate Web-accessible multimedia class files for the instructor and students [13]. Chen et al. have developed a system for test taking using handheld devices [14].

In this paper, we will present Smart Classroom that use pervasive computing technology to enhance collaborative learning among college students. We integrate mobile and handheld devices, such as Personal Digital Assistants (PDAs), with fixed computing infrastructures, such as PCs, sensors, etc. in a wireless network environment inside a classroom. The mobile devices in Smart Classroom are situation-aware in the sense that they can capture different situations in a classroom dynamically to form ad hoc networks to facilitate both student-student collaborations and student-instructor interactions. We will show how using the Smart Classroom can greatly benefit a senior group software engineering project course.

2 Background: Collaborative Learning

Collaborative learning creates an environment that the teacher involves students in doing things and thinking about the things they are doing and reaches students who otherwise might not be engaged [15]. Collaborative learning encourages active student participation in the learning or small group learning. In collaborative classrooms, where every student learns from everyone else, no student is deprived of the opportunity for making contributions and appreciating the contributions of others. Collaborative classrooms have the following four general characteristics [15-16]:

S1) *Sharing knowledge*: Teachers have vital knowledge about the course content, skills, and instruction, and provide that information to students. In a collaborative classroom, the teacher also builds upon the knowledge, personal experiences, language, strategies, and culture that students bring to the learning situation.

S2) *Sharing ability:* In a collaborative classroom, the teacher encourages students' use of their own knowledge, ensures that students share their knowledge, expertise and their learning strategies, treat each other respectfully, and focus on high levels of understanding.

S3) *Mediation:* In a collaborative classroom, teachers act as mediators to adjust the level of information since successful mediation helps students connect new information to their experiences and to learning in other areas, helps students discover what to do when they are stumped, and helps them learn how to learn.

S4) *Heterogeneity:* In a collaborative classroom, heterogeneous groupings of students enrich learning in the classroom since the perspectives, experiences, and backgrounds of all students are important for enriching learning in the classroom.

The first two characteristics capture the nature of relationships between the teacher and students in a collaborative classroom. The third characterizes teachers' new approaches to instruction. The fourth addresses the composition of a collaborative classroom. The Smart Classroom enhances all of the above characteristics of collaborative learning. A conceptual figure of Smart Classroom is shown in Figure 1. In the next section, we will describe the features of the Smart classroom.

3 Major Features of Smart Classroom

Our Smart Classroom facilitates collaborative learning using RCSM, which is a middleware for pervasive computing applications. Devices in a smart classroom can be divided into two categories: infrastructure-devices and mobile-devices. The infrastructure-devices are stationary in each classroom, and provide the necessary information to the mobile-devices, such as the relative locations of the mobile devices with respect to those of the infrastructure-devices, and the light intensity of the classroom. The mobile devices usually belong to the students and the instructor. Using these mobile devices, the instructor and the students can actively interact among themselves in a classroom.

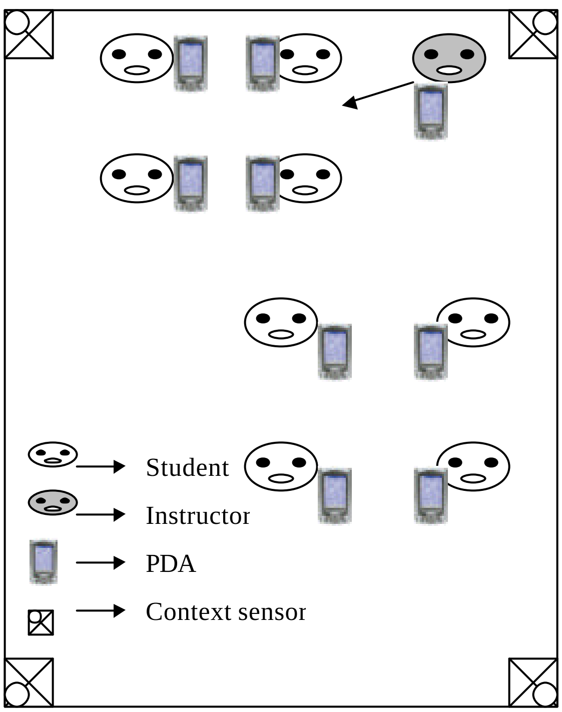

Figure 1: A Smart Classroom.

In our current implementation, we use PDAs as mobile devices. The infrastructure-devices currently consist of PCs and PDAs with the capabilities of location and light detection. Both types of devices use our RCSM with different types of collaborative applications. We will describe the major features of our Smart Classroom below and discuss how these characteristics facilitate collaborative learning:

A) Ephemeral Group Formation and Communication: Group discussion is one of the most important functionalities of a Smart Classroom to facilitate collaborative learning. Depending on the current situation, such as the location of the current classroom, class schedule, and availability of other group members, the PDAs in the classroom can form device groups so that students can collectively work on various in-class exercises. These device groups are dissolved as soon as the group-forming situations are no longer true. This feature of Smart Classroom addresses S1) and S4). In addition, an instructor's PDA can dynamically join a student group to monitor and evaluate a group's progress and provide timely feedbacks during a classroom exercise. This feature addresses S2).

B) Situation-Aware Interactions Among PDAs: In order to address S3) among students and the instructor in different cases, we use our RCSM in PDAs to provide situation-aware interactions among PDAs. In this type of interactions, different PDAs detect each other dynamically and exchange useful information depending on their respective and desired situations. For example, at the beginning of a class session, the instructor's PDA detects students' PDAs in the classroom and distributes lecture slides to the students' PDAs whenever the instructor becomes ready to start the lecture by dimming the light if a projector is used.

4 Functionality of Smart Classroom Applications

In this section, we will describe how our Smart Classroom application suite facilitates collaborative learning applications. Our Smart Classroom application suite facilitates different collaborative learning activities of a student, an instructor, and a teaching assistant (TA). The suite also provides different functionalities for communication between the students, the teacher, and the TAs. The functionalities of Smart Classroom Applications are listed below:

i) For a single student

a) The application suite reminds the student of his/her homework and class schedule based on current time and current location.
b) The application module will synchronize the lecture notes between a student's PDA and desktop computer before and after class.

ii) For instructor/TA

a) The application suite synchronizes the lecture notes between instructor or TA's PDA and desktop computer before and after class, since desktop computers have the original lecture notes.

iii) For student-to-student communication

a) The application suite enables students to exchange and share their documents in drawing.
b) It also enables students synchronize drawing document among their PDAs.

iv) For instructor/ TA-to-students communication

a) The application suite distributes teaching material (lecture notes/survey forms/grade sheet/course schedule) from instructor or TA to all students at proper situations, such as: at the beginning of a class, when light is dimmed and noise is low.
b) The instructor can create exams for students and groups by using the application suite. The instructor can also send exams to the students and groups and collect answers; grade and send the grade back to the students by using the application suite.

v) For student-to-instructor/TA communication

a) The application suite facilitates students to store their questions or concerns in text format in their PDAs. When the instructor or TA is available (in classroom), the questions are automatically transferred to the instructor or TA's PDA.

b) Students submit their progress report in a similar way by using the application suite. At the end of a class, their reports are submitted to the instructor or TA automatically.

c) Students make appointments with the instructor using their PDAs to send the request to the instructor's PDA and get a confirmation using the application suite.

d) Students write answers of the exams and send answers to the instructor using the application suite.

e) Students run and display their homework on the PDAs and project it on the screen with the help of the application suite.

5 Development of Smart Classroom using RCSM

In this section we will discuss how to use our Reconfigurable Context-Sensitive Middleware (RCSM) to develop our Smart Classroom. RCSM architecture is shown in Figure 2. In the Smart Classroom, the instructor and students all carry their PDAs. Each PDA has different kinds of sensors. Students' PDAs dynamically form mobile ad hoc networks based on proximity and specific contexts, such as locations, light intensity, to collaboratively address a specific problem. Application software is interoperable across different programming languages, PDAs, and mobile ad hoc networking protocols.

1) Situation-Aware Application Development Framework: We have developed an application development framework in RCSM to facilitate the development of situation-aware application software. We have developed a situation-aware interface definition language (SA-IDL) to specify the "situation-awareness" properties of application objects. As described in [5], this allows the separation of an application object into a situation-aware interface and a situation-independent object implementation. An SA-IDL specification can also be used to generate a custom-made situation-analyzer for an application object. A situation-analyzer performs the necessary situation analysis on behalf of an application object [5].

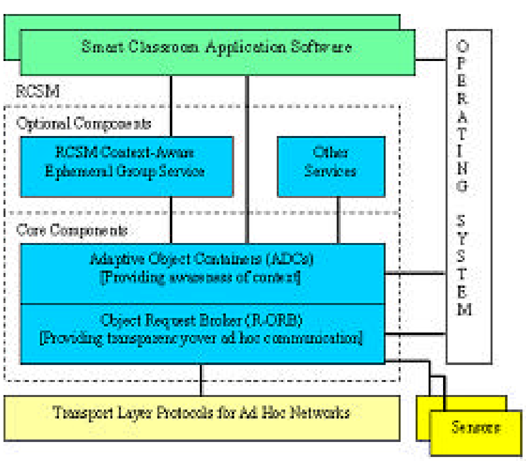

Figure 2: RCSM architecture in our Smart Classroom test bed.

2) Situation-Aware Object Request Broker: We have developed RCSM Object Request Broker (R-ORB) to facilitate the following runtime services [4-6]:

a) Situation Data Acquisition: Situation-aware applications may need runtime situation data from various sources. These sources can be local to the device or remote. In cases of remote sources, situations must be collected periodically. R-ORB provides this basic facility. Situation-aware applications may also need to exchange information with remote applications in a point-to-point or ad hoc group settings.

b) Situation-Aware Communication Management: R-ORB provides a lightweight framework for transparently connecting distributed and mobile situation-aware application objects over mobile ad hoc networks. The R-ORB protocol spontaneously senses the peer devices in the vicinity and establishes short-duration connection by efficiently analyzing the situation-readiness and the desired communication partners of specific application objects. In addition, R-ORB provides a lightweight client-server communication primitive for the application objects to communicate with stationary or enterprise computing resources.

For mobile devices used by the students and instructors, we have chosen the Casio E-200 PDAs, because the running versions of RCSM, including R-ORBs, were already implemented in these PDAs. Each PDA used an Intel Strong Arm 1110 with 206 MHz clock speed CPU. Each PDA had Flash ROM and RAM of 32 MB and 64 MB respectively. Each PDA was also equipped with a D-LINK Air DCF-660W Compact Flash 802.11b adapter. These adapters were configured in mobile ad hoc network configurations to support ad hoc networking for mobile users in Smart Classroom.

For infrastructure development, each PDA is also programmed to function as location beacons. In addition, each PDA is also connected to external hardware components to provide noise, light, and motion sensing support. To accomplish this, each PDA was connected with a Trenz Electronic USB-compatible Xilinx Spartan II FPGA board equipped with noise, light, and motion sensors.

For the Smart Classroom application suite, we have developed the situation-aware ephemeral group communication service (SAEG) and a chat module. We are currently implementing information dissemination service (IDS), exam-taking and grading tools using the facilities provided by RCSM.

6 An Example

In this section, we will show how we use our Smart Classroom for the class of CSE 461 Software Engineering Project I, which requires intensive group collaborations among students to complete a software design project. CSE 461 provides students with hands-on group-working experience. Students and the instructor in CSE 461 carry their PDAs. Students are provided with the group project requirement specification and development schedule. They follow a specific project process model to develop the software project. Students finish the requirement specification, software analysis and software design on schedule. Students develop their risk management plan. Each group member participates in the project actively and communicates with each other verbally and exchange documents through their PDAs in the classroom. Students of each group view the analysis and design documents of the projects, discuss, and make necessary modifications and generate one final copy and distribute it among themselves. The instructor frequently interacts with various student group and monitors their progress in the classroom.

The classroom of CSE 461 needs facilities for group collaboration and student-instructor interactions, so that student can come up with a successful design document. Group collaboration exhibits the characteristics S1), S2) and S4) of collaborative learning. In group collaborations, the PDAs in the CSE 461 classroom can form device groups so that students can collectively work on a design document depending on the current situation, such as the locations of the students in the classroom, class schedule, and availability of other group members. Thus, CSE 461 classroom has the characteristics S1) and S4). The situation-aware interactions among the PDAs in a group collaboration in CSE 461 exhibit S2). The instructor's PDA can dynamically join a student group to monitor and evaluate the group's progress and provide timely feedbacks during a classroom meeting. This type of Student-instructor interactions has the characteristics S2) and S3). Our Smart Classroom addresses all these four characteristics S1)-S4) by facilitating both group collaborations and student-instructor interactions capabilities, which are described below:

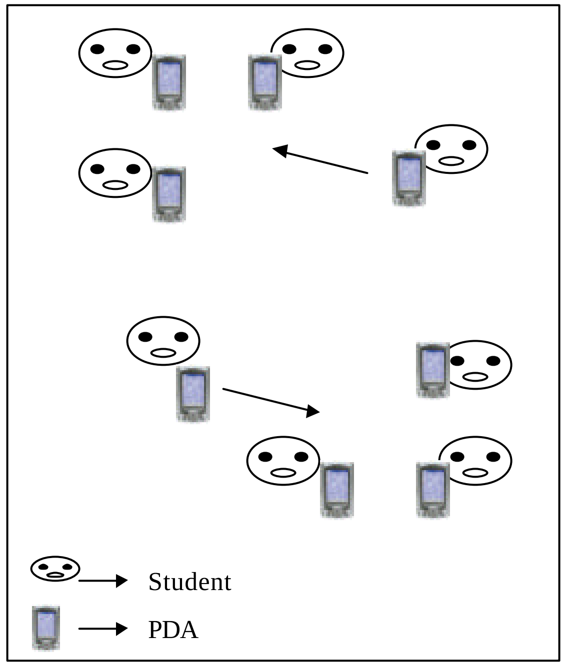

Figure 3: Student groups are formed in the Smart Classroom.

Group collaborations: The students in the classroom start to form groups as shown in Figure 3. The location detection sensor of RCSM detects the location of the students' PDA inside the classroom. SAEG of RCSM establishes communication between two or more PDAs of the same group when they are in communication range and groups are formed. Additional students are coming in to join the groups as shown in Figure 3. Students of the same group come closer. The location detection sensor of RCSM detects the locations of the students' PDAs inside the classroom. SAEG of RCSM establishes communication between two or more PDAs of the same group when they are in communication range with each other and thus the group communication is established. This is shown in Figure 4. Students discuss in groups and send design documents to group members and give feedback and collaboratively generate a design. The application suite is used for sending and receiving design documents and feedback.

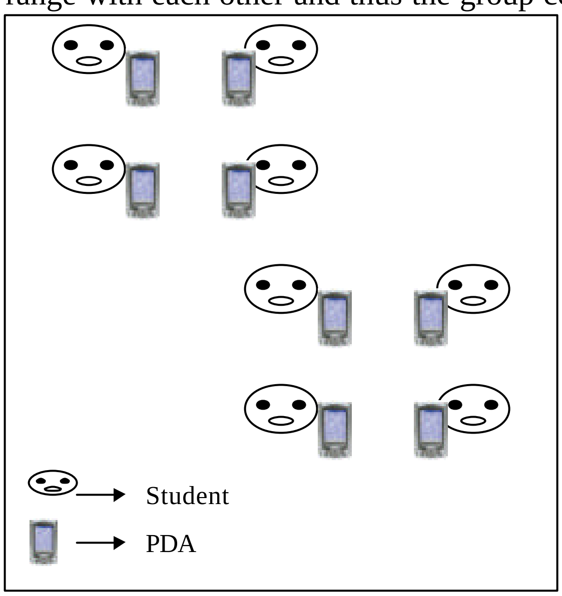

Figure 4: Students are discussing in groups in the Smart Classroom.

Student-instructor interactions: When the instructor approaches a group, the instructor downloads the group discussion material, such as design documents, as shown in Figure 5. The instructor goes through the design documents and gives feedback to the group. The application suite of our Smart Classroom is used for receiving and sending design documents with comments from the students' PDAs to the instructor's PDA. The location sensor is used to check the vicinity of a group and the instructor's location. The group members leave when the discussion session is finished. The SAEG of RCSM is used for termination of groups smoothly.

7 Discussions

In this paper, we have presented a Smart Classroom, which facilitates collaborative learning using pervasive computing technology. It is designed to increase the level and quality of interactions between students and instructor in a classroom. The functionalities of the Smart Classroom, including an example course, have been presented. We have already developed the RCSM Object Request Broker (R-ORB) to facilitate situation data acquisition and situation-aware communication in the Smart Classroom. We have also developed an application development framework in RCSM to facilitate the development of situation-aware application software for the Smart Classroom. The implementation of situation-aware ephemeral group communication service (SAEG) and a chat module for group collaborations and student-instructor interactions of the Smart Classroom have been completed. Currently, we are evaluating the Smart Classroom with various scenarios, and implementing information dissemination service (IDS) and file transfer service for the Smart Classroom. Future work includes implementing security service, exam-taking and grading tools using the facilities provided by the RCSM and extensive evaluation of our Smart Classroom. In addition, a number of new features in Smart Classroom such as appointment making, question answering, and schedule creating, will also be developed.

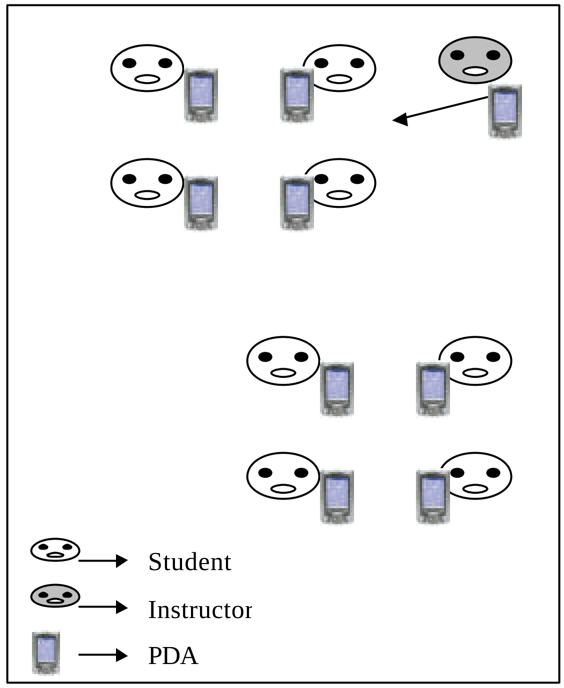

Figure 5: Instructor is giving feedback to a student group in the Smart Classroom.

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