Hybrid Approach of Augmented Classroom Environment with Digital Pens and Personal Handhelds

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Abstract. We have been developing a system *AirTransNote*, a computer-mediated learning system that employs digital pen to realize paper-centric augmented classroom. Although the approach was sophisticated, it restricted feedback effects which potentially improve learning. To maximize the feedback effects of the system, we present a hybrid approach of augmented classroom environment. We classified the type of feedback loops in terms of the hybrid approach and improved the system to accomplish the functions by adding (1) note browsing interface for handheld, (2) worksheet editor for teachers, (3) handwriting character recognition engine for versatile use, and (4) HTTP embedded server function for flexible reference of collective results and notes. We also conducted a feasibility study and investigated the effectiveness of the immediate feedback under the hybrid approach.

1 Introduction

Mobile and wireless networking technologies accelerate the activities of computer-mediated learning and CSCL as stated by Roschelle and Pea[1]. The potential of these technologies is recognized and investigated[2], and many systems [3],[4],[5],[6] have been proposed to improve the effect of collaborative learning by sharing student notes and annotations in a classroom environment. Most of the systems employ digital devices such as tablet PCs and handheld computers to capture notes.

In contrast, we have developed a system *AirTransNote* (ATN) for reducing the additional effort for students. ATN employs paper-centric approach[7] to augment the learning and teaching activities in the traditional classroom by sharing notes. ATN can capture a student's note written on a regular paper with a digital pen device and transmit the note to the teacher's computer immediately. Moreover, our system provides a remote for teacher to encourage the natural interaction in a physical classroom space[8]. The remote attaches a RFID reader to provide intuitive selection of student's note by touching it. Typical scenario of learning with ATN is also described in [8].

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Though ATN employs handhelds for transmitting student notes, we have not fully considered the effect of the handhelds because we mainly focused on the paper-centric approach. However, we have noticed that the effect of ATN system can be improved when we make full use of the handhelds. When the full support of handhelds is realized, ATN can be used to activate collaborative and cooperative learning among students as well as the automatic personal reply. In this paper we discuss the characteristics of ATN in terms of hybrid approach which utilizes both paper and handheld as media of CSCL activities. Additional functions developed toward the hybrid approach are also described.

2 AirTransNote as Hybrid Approach

We considered that the paper-centric approach[7] was epoch, but "transmitting student's note to a teacher" was insufficient for evolution of the learning environment since some feedback loops were not established. To magnify the effect of the note sharing function, the learning system should afford the feedback loops as much as it can. We enumerate the type of the feedback loops and summarize advantages of student handhelds we employed as follows.

(1) Student Self Feedback Loop. Maruyama and colleagues have adopted Anoto-based pens[1] to collect students' activities in English as second language class[9]. In order to synchronize notes, the student taps on a "send" region of paper or puts the pen on the cradle. Using Anoto alone is fairly simple, but students neither confirm nor fix the note captured and transmitted. Handheld can supply the students functions not only revision of notes but also reflection, because the note displayed on the handheld device (different visual to the note itself) might somewhat arouse consciousness with meta perspective. In either case, the revision function will ease students' anxiety about publicizing notes.

(2) Between System-student Feedback Loop. With the handheld the student can get individual feedbacks from the system. Even if the feedback is simple like correct/incorrect messages and sounds, the students will be encouraged to progress. The feedback is similar to self-checking of the result with answer, but a feeling of satisfaction for automatic checking will be higher than that of self-checking.

(3) Between Teacher-student Feedback Loop. The between teacher-student feedback loop is established by guidance from the teacher to the students. Before the guidance, the teacher should recognize the status of the students. AirTransNote provides note browser and summarization list. From the note browser, the teacher can annotate the notes. The annotation is transferred and displayed to the student handhelds. From the summarization list, the teacher can grasp the progress of the students. Thus the teacher can guide students by transmitting advisory annotations as well as contacts directly.

[1] `http://www.anotofunctionality.com/navigate.asp`

(4) Between Students Feedback Loop. The handhelds for student have great potential to freely exchange the notes among the students and to score them. The collaborative learning activities will work effectively if the teacher controls the transactions of the note sharing activities properly.

3 System Improvement

In order to maximize the number of available feedback loops and to enhance the learning effect, we have improved our ATN system.

3.1 For Student Self Feedback Loop

ATN Manager, software which runs on a teacher's PC, can overlay students' notes on page images, whereas ATN Transmitter (prior software which runs on a student handheld to send notes) displays the notes without page images. As a matter of course, showing page images is more appropriate for the student to recognize the note. Therefore we have developed ATN Mediator as a successor of the transmitter. Figure 1 shows the snapshot of the handheld. A student can see both notes and annotations with the page image. Thus the student can grasp the context of notes and recognize what the student has sent. The view can also be used to confirm whether a calibration process goes well or not. The mediator scrolls the note view to make visible the area where the student writes or taps on the paper. Thus the trouble of view control can be reduced.

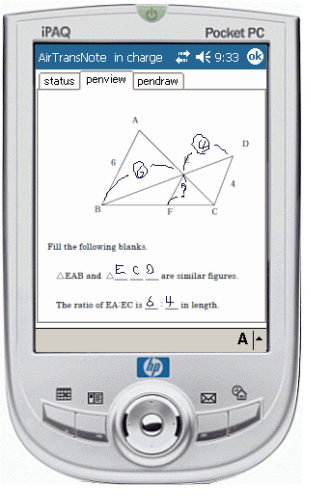

Fig. 1. Note browsing interface for handheld (ATN Mediator)

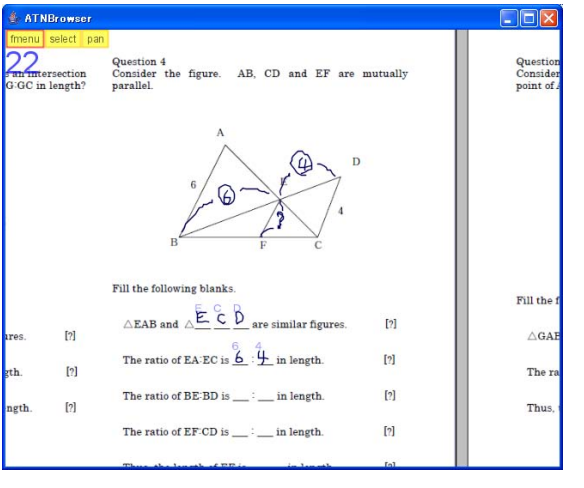

Fig. 2. Note browsing interface for teacher's PC (ATN Browser)

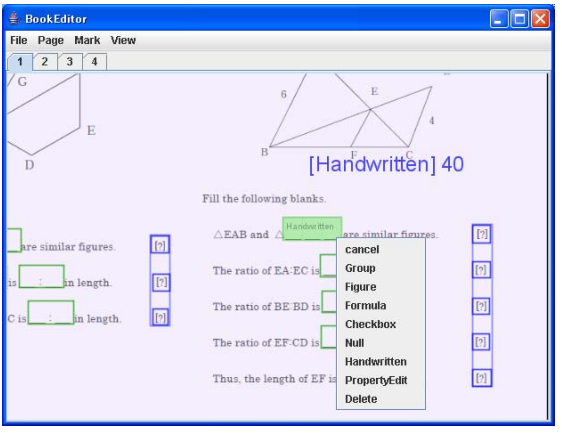

Fig. 3. Worksheet Editor for teacher

Fig. 4. Region Property Editor

3.2 For Between System-Student Feedback Loop

The between system-student feedback loop is significant for computer-mediated learning environment since it can provide immediate responses to the students. We have already implemented a mechanism which recognizes simple check-boxes. But in order to amplify the effect of note, we have embedded a handwritten character recognition engine developed at Nakagawa laboratory, Tokyo University of Agriculture and Technology[10] with our system. ATN Manager can interpret student's handwritten notes and return feedback to the student's handheld. The result of recognition can also be shown on the screen (Figure 2).

To make the system recognize notes on a paper, the teacher should prepare a worksheet which contains specifications on how the notes are processed. We have developed a page editor to design the worksheet. Figure 3 shows the interface of the page editor. The teacher first creates a new page by dragging a worksheet image file (jpeg, png, and gif) and dropping it to the window. Then the teacher draws rectangles to set regions on the page and specifies the type of recognizer for the regions. After that, the teacher enters properties of the region at the editor window (Figure 4). The region properties consist of title, preferences for recognizer, and feedbacks. When the result matches with the properties beginning with '<u>fb</u>-' prefix, pre-defined <u>feed</u><u>b</u>ack is generated. In substitution for the editor, the region properties can be specified by loading a text file.

3.3 For Between Teacher-Student Feedback Loop

The teacher through the teacher's remote as well as the PC should refer a collective result of recognition. We could implement an original browsing interface for the collective result from the remote PDA, but we decided to utilize a standard web browser to watch the result. The standard web browser is suitable for watching a result whose structure may dynamically change. For that reason,

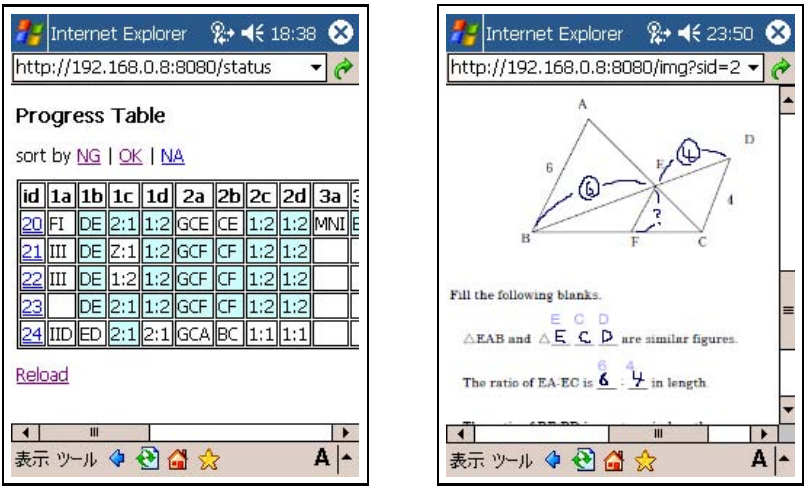

Fig. 5. Collective result (left) and note image (right) rendered by standard web browser on Pocket PC

we have combined a web server with AirTransNote. We chose OOWeb[2] HTTP server written in Java to embed. The embedded web server responses latest collective results and note images in png format when the teacher requests from a browser (see Figure 5). The teacher can find the students in need of guidance by sorting the order of the table rows by number of incorrect or blank, and then browse the note image from the remote.

3.4 For Between Students Feedback Loop

The students can browse other students' notes as the same HTTP way through their handheld. In addition to this, the system can send a URL to the handheld to open a web-page as feedback. Therefore the students can share their notes or ideas and encourage them by voting on each others.

4 Related Works

EduClick[11] employs wireless IR remotes for collecting student's answers in class. The simplicity of EduClick will contribute casual and wider use, but its shortcoming is that it only accepts selection-based responses. Singh et al. [12] developed a collaborative note taking system in which the students could reuse the text in teacher's slide or another member's note by tapping to reduce the typing. Our system employs PDA as a device for transmitting note. Though the real estate problem even exists with our system in displaying comments, the digital pen can alleviate the efforts of inputting. Tallyn et al. [13] also pointed out the advantages of augmented paper media in educational settings.

[2] http://ooweb.sourceforge.net/

A Tablet PC is similar to a digital pen device in collecting time-stamped notes. The Tablet PC is more flexible than the digital pen in that it can modify the notes and its properties such as colors and thickness. Also the display can reflect the feedback with overlays. Thus many systems have been developed [14],[4],[2]. However, Tablet PC is large, heavy and expensive. Moreover, it does not provide the natural feeling of taking notes, which is significantly different from taking notes on real paper. We consider that familiarity is more important than flexibility especially in early stage of the computer-supported lecture.

5 Feasibility Study

We conducted a feasibility study to collect the comments of the ATN system with sound feedback and direct touching interface to select note by teacher's remote. We collected 20 volunteer participants all of them were graduate students. We prepared two worksheets, geometry test and IQ quiz, with replies according to the answer. When the answer is correct, the mediator plays a "ding" sound; otherwise, it plays a low buzz sound immediately. The teacher utilized the remote to close up to the student's answer during a reviewing session after the each test. We spent 15 minutes for test session and 5 minutes for reviewing session for each worksheet. Figure 6 (a) and (b) show scenes of the study.

(a) (b)

Fig. 6. Scene of the feasibility study

Lessons Learned. Figure 7 shows the questionnaire items and the results. Regarding the immediate transferring function of notes, 75% of participants were satisfied (Q1). The result of Q2 shows many participants agreed with the effectiveness of sharing notes. Regarding the stress in sharing, in comparison to our previous experiment on mathematical class on 40 high school students[7], few participants mentioned stress in this feasibility study. We can pose a hypothesis that the following four factors would affect either aggravation(+) or alleviation(−) of the stress: (1+) Difficulty and formality of the problem, (2+) Smaller answer area which prevents rewriting, (3+) No confidence without feedback, and (4−) Physical note selection by direct touching operation. We have to investigate the effect of each factor in further experiments.

We had adopted sounds for main feedback in this study. 55% of participants thought that the feedback is important (Q3) because it helps confirm the result.

But some participants said that the system is very noisy, so they cannot concentrate. Considering the higher acceptance rate in (Q1), the real-time feedback itself is supported. However, we should carefully design the feedback, especially volume levels in sound playback.

From the teacher's view, the remote was useful for closing up to a student's note immediately. The teacher could easily select a student and let the student explain the answer for the class. Though the teacher tended to select students who sat on aisle seats, this tendency is covered by relaxed seat arrangement and teacher's mind.

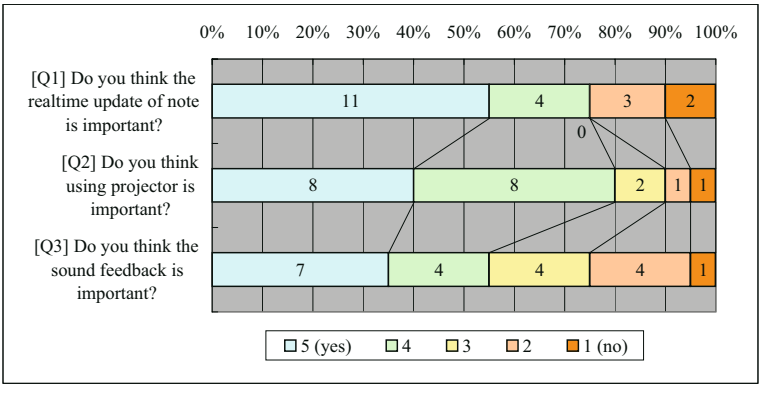

Fig. 7. Result of the questionnaire

6 Conclusion

The paper-centric design of ATN is effective since it frees one from PC operation. However, the power of the devices introduced is underutilized while the system strictly applies the design criterion. In order to maximize the power and effects, we propose a hybrid approach which utilizes both a digital pen and a handheld for collaborative learning. We have considered four feedback loop types as criteria for hybrid design and improved the ATN system in terms of the criteria. Moreover, we conducted a feasibility study to clarify the effectiveness of the immediate feedback. Though the activity of the study only includes publicizing notes on a large shared screen, we will evaluate the effects of collaborative learning activities including a "between students" feedback loop. We will also apply the hybrid system to problem-posing style learning activity because the personal handheld can support the advanced problem-posing works.

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