eFuzion: Development of a Pervasive Educational System

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ABSTRACT

Established as a research project at the University of Illinois in the spring of 2002, eFuzion has proven to be a valuable and effective pedagogical set of tools. It provides the capacity to both mentor and assess students individually, both during and outside of class. In the summer of 2002, a study we conducted revealed that eFuzion's in-class tools increased student's final grade by more than 6 points. In this paper we describe the evolution of our system and experiences leading up to our "Classroom of the Future" demo for the Grand Opening of the Thomas M. Siebel Center for Computer Science. We conclude with a discussion of our future plans for eFuzion.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *Collaborative learning, Computer-assisted instruction (CAI), Distance learning.*

General Terms

Design, Human Factors.

Keywords

Classroom Presentation, Tablet PC, Digital Ink, Lecture Notes, Collaborative Learning, Educational Technology, Wireless Learning Environment.

1. INTRODUCTION

Education requires interaction among students and instructors. Successful educational technology fuels educational collaboration. When the student is stymied by the lack of direct contact with his or her teacher and peers, modern technology offers new forms of communication that break down traditional barriers to education.

The rapidly evolving nature of education poses significant challenges to learners and educators. Research has consistently shown that two-way communication between teacher and student can significantly enhance learning rates and overall student performance [13]. Similarly, interactions between students can enhance peer-to-peer discovery, problem solving, and knowledge

acquisition. However, increasing class sizes make it difficult to provide a maximal level of communication in the traditional lecture environment. Facilitating direct communication is even more difficult (though no less desirable) in distance learning settings.

eFuzion was created to improve interaction among staff and students in large classes (allowing their size to become a benefit) and to provide tools for the instructor to facilitate teaching. In this paper we describe the development of eFuzion, culminating in a demonstration for the Grand Opening of the Thomas M. Siebel Center for Computer Science. We detail the lessons learned which will facilitate the design and development of pervasive educational software systems.

2. A BRIEF OVERVIEW OF EFUZION

eFuzion is an interaction-based classroom learning environment where participants in a course - instructors, students, and teaching assistants - have access to computing devices both inside and outside of the class. During lectures, faculty use the presentation tools that eFuzion provides to annotate prepared slides with notes and examples, which are transmitted over the wireless network to the student's computing devices. Students can then use the same tools to add their own notes to the presentation and save the annotated presentation for later reference.

Over the past five years, three successive revisions of eFuzion have been completed. Versions include a graphical newsgroup that supports communication between students and faculty. Students can post questions to the newsgroup without interrupting the flow of the lecture. Teaching assistants can answer questions from anywhere and at any time, either during lecture when they have the option of passing questions on to instructors or asynchronously during non-class time. The eFuzion newsgroup enables the incorporation of lecture notes into posts so students can better articulate questions. Students can embed diagrams in their questions. Similarly, teaching assistants can annotate over those diagrams in their responses.

Additionally, eFuzion provides facilities for incorporating active learning exercises into the lectures, providing instructors with instant feedback on student comprehension in the form of quizzes and interactive polling (figure 1).
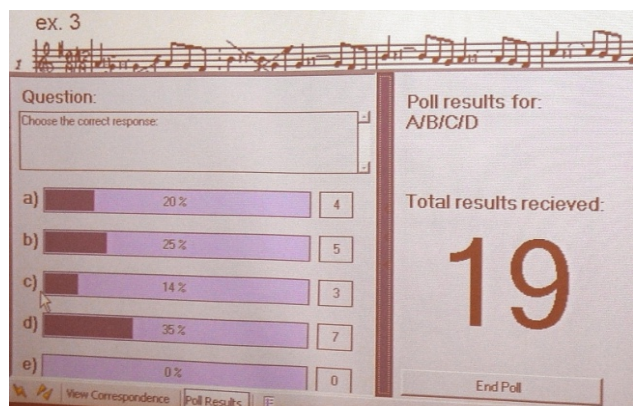
Figure 1: A snapshot of eFuzion as results are being registered and displayed in real-time on the instructor's display.

3. HISTORY OF EFUZION

Motivated by early pen-based input devices, the first version of eFuzion was developed in the fall of 2001 by a two undergraduate students to ease the burden of student note taking [11]. They wanted to build a system that could support seamless integration into our large lecture halls in addition to supporting our off-campus students in our Illinois Internet Computer Science Program (I2CS) [19] where bandwidth for students using dial-up connections was limited. The major feature that distinguished their system from others at the time was the integration of a vector graphics library. Vector-based representations of drawings are much more compact than bitmap (also called raster) representations, and therefore reduced the bandwidth requirements to acceptable levels.

In short, eFuzion supported the synchronization of vector-based graphics drawings and modules. Vector graphics created at one computer could be quickly replicated, allowing manipulation of the graphic(s) in real time. This enabled the creation of the graphical newsgroup and other features within the eFuzion application.

Four months later, the software was piloted in a course on data structures for non-majors in the spring 2002 semester and in a database systems course the following summer.

As the software was evolving, the underlying hardware was also improving. The first prototype was deployed on HP Jornada 680 handheld devices, while the spring pilot used an early Hitachi pen input device.

The study conducted in the summer of 2002 used a combination of Fujitsu B series pen-input based laptops and Dell desktop replacements. This led to the realization that pen-input is an essential feature for the support of in-class note taking. Pen input allows students to create their own notes in addition to viewing the instructor's slides. Figure 2 illustrates the first prototype eFuzion interface.
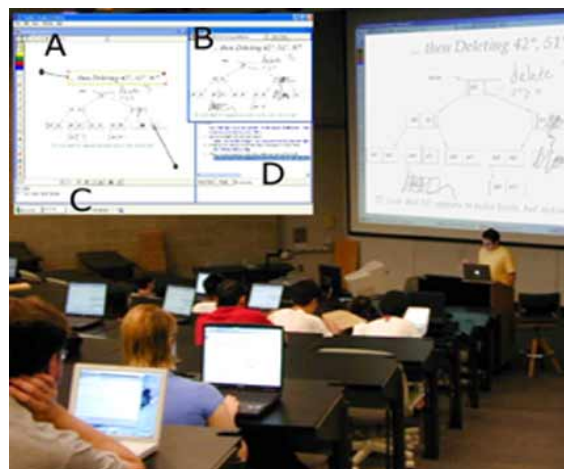

Figure 2: Student's view of eFuzion (upper left). Areas include: instructors slides and notes (B), student's clipboard (A), student notes (C), and graphical news group (D).

These early experiences were highly informative. One notable change in the classroom scenario was the freedom to move about the room using a wireless tablet. This allowed the instructor to directly engage students. A major concern with the early pen-input devices was their inherent limitation on screen real-estate and processing power. This led us to write future versions of the software for laptop computers, and ultimately the Tablet PC.

During the study in the summer of 2002 eFuzion's effectiveness at enhancing learning was measured [17]. The results of this study showed that eFuzion increased student satisfaction with the course and the amount of material learned. These results support our belief that the use of computing devices in the classroom can be of substantial benefit. However, the study also revealed significant drawbacks in the use of traditional laptop computers in a classroom environment. Students were "unhappy" with the size and weight of the devices; the standard keyboard/screen configuration of a laptop interfered with the student's ability to see the instructor, and the absence of an interface more conducive to traditional note taking.

The next generation of eFuzion was designed for the newly available Tablet PCs. A Tablet PC-based version of eFuzion was completed in the fall of 2003.

4. "CLASSROOM OF THE FUTURE" DEMONSTRATION

To demonstrate our vision for eFuzion-based instruction, in the spring of 2004, we prepared a presentation for the grand opening of the Thomas M. Siebel Center for Computer Science at the University of Illinois [21]. Beyond illustrating the use of eFuzion in the classroom we also wanted to enhance our system to support pervasive computing including the integration of wireless mobile devices and remote classrooms (figures 3 and 4).
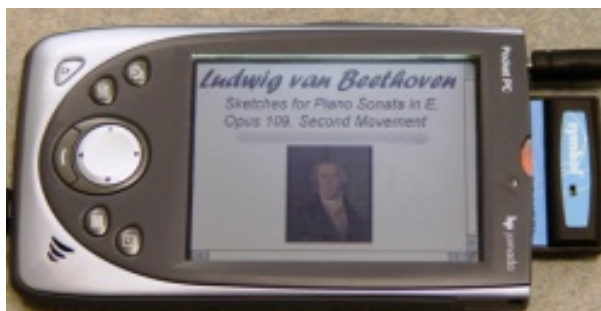
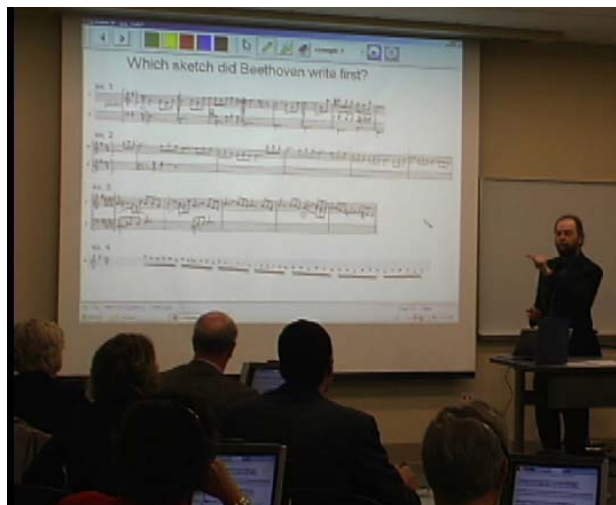**Figure 3: The presentation as received on a wireless PDA.**

Figure 4: Professor Garnett of the Music Department teaches about Ludwig von Beethoven's creative compositional process.

To extend our learning environment to remote classrooms we transmitted bidirectional high definition video, which was streamed through the ConferenceXP infrastructure [20]. We also modified the eFuzion system by creating an ink messaging and distribution architecture to support mobile devices.

Our ink distribution architecture as illustrated in figure 5 is described below. First, an XML message is created from an ink stroke or other event. Each message is distributed by our ubiquitous infrastructure to each client. The infrastructure provides both multiple connectivity options and information in a format suitable for diverse clients. Once received, the message is rendered by each of the clients.
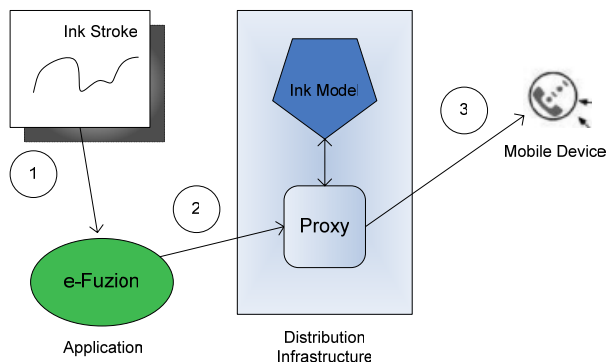

Figure 5: Path of an ink stroke from the instructor to the clients

4.1 eFuzion Message Formats

Several message types are used within eFuzion to exchange data. These include messages indicating the connection of new clients, the creation and selection of documents, the insertion, deletion, and selection of slides, and the drawing of ink strokes. All messages are exchanged in an XML format that is accessible to any web-enabled device.

Since Microsoft Rich Ink [11] is unique to Tablet PC's, it cannot be directly integrated without required hardware and software on other machines. eFuzion's ink message format represents ink related information in a general form usable on a variety of devices. An attribute list describes data available at each point including location, pressure, and timing information. Data applicable to the whole stroke includes identification, color, thickness, and scaling information.

This format allows the maximum amount of information to be preserved for rich clients, while other devices use attributes they are aware of. With the proper selection of default values, rich clients can display strokes created on other devices with an appearance and functionality similar to that of ink created natively.

4.2 The Distribution Infrastructure

The role of the distribution infrastructure is to provide transparency in both format and connectivity among devices. To achieve format transparency, the server maintains an ink model encompassing the information transmitted in eFuzion ink messages.

The underlying pervasive computing infrastructure supports several types of connections, including CORBA connections and socket-based connections using a proxy. The socket-based connections can be established over unicast and multi-cast over carriers such as GPRS, 802.11, and WAN networks. A classroom may effectively transcend the walls of the campus to clients connected anywhere anytime.

The most important role of the server is to adapt multimedia content to an acceptable format for the target device. The server understands how to reformat ink strokes and slides among different formats. The clients can then select the information they require upon receiving a notification of new data.

4.3 Clients

Clients in our system fall into two classes. First-class clients, such as Tablet PCs, support rich multimedia capability in the form of ink and video. Second-class devices comprise web terminals, and thin clients such as PDAs and smart phones. Web terminals include both embedded computers and public access terminals such as library computers. These devices are not capable of running software to support rich ink natively. To display ink information on such devices we use a custom ink renderer that utilizes the information obtained from the model.

5. POST GRAND OPENING

Research in pervasive computing affords us an opportunity to investigate new paradigms for learning where dependencies from temporal and spatial factors are rendered obsolete. The integration of these technologies into an educational setting will result in a

significant reduction in cost and a commensurate increase in the effectiveness of instruction [2].

Our original centralized client-server system was not mature and extensible enough to support the integration of pervasive services. As a result, we created a proxy-based architecture to take advantage of the ubiquitous nature of smart devices [15]. This experience motivated us to envision the potential of a pervasive learning system.

We have now embarked on the development of an entirely new version of eFuzion. The goal of this development is to provide for user-level extensibility through scripting. This version, which is expected to be available for public distribution by August, 2005, will achieve several goals.

The new version will allow out students to contribute code for new features without their having to master a large code base. It will permit customization of generic facilities including student polling. The construction of subject-specific modules, such as drawing logic devices in a computer architecture course, or the calculation of derivative security value in a finance course, will be simplified. It will also permit experimentation with and fine tuning of all the various features. Details will be made available on our website at http://edtech.cs.uiuc.edu.

6. RELATED WORK

A number of educational Learning systems have been developed [3, 5, 8, 14, and 18]. Incorporating pervasive technologies into laboratory settings has been studied by [16], and [9] who built a real-time collaboration infrastructure for interactive laboratory experiments using the ConferenceXP technology.

Studies have been conducted including research on inking in educational settings [1]. The integration of laptop computers in classrooms was studied in [7]. In [12] a system describes the lifecycle and support requirements of small temporary notes. Ephemeral inking marks are shown to fall into common patterns with meaning that can be interpreted in [4].

In [6] the designers of eClass (formerly Classroom 2000) reflect on their experiences and provide further insight into how ubiquitous computing can help solve some of the problems encountered when assessing their work, automated capture and access in the classroom. In order to analyze and validate educational technologies, we must take a holistic approach through pervasive computing. The redevelopment of eFuzion has made our system different than the aforementioned in that it is constructed from a distributed component architecture based on a pervasive computing infrastructure.

7. CONCLUSION

Through the development of eFuzion we enable the creation and validation of a pervasive educational system. Our system reinforces the traditional pen and paper paradigm while taking advantage of pervasive technologies. The extensible version of eFuzion, currently under development, may enable a generation of fully context aware classroom applications.

8. ACKNOWLEDGMENTS

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