Expanding Education through Active Space Collaboration

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Abstract

In this paper we introduce a system called e-Fuzion based on using computing devices, such as Tablet PCs, that empower students and teachers with better technologies for educational interaction. We propose an e-Fuzion integration with ubiquitous computer environments of smart devices and active spaces using a system called Gaia. At present, e-Fuzion facilitates electronic communication in a seamless, integrated classroom, giving students additional ways to interact with faculty and each other. e-Fuzion encourages students to participate actively even in large scale class settings. By integrating e-Fuzion into an active space, we enhance the effectiveness of the existing system by taking advantage of the ubiquitous nature of smart devices and their unique communication capabilities. The end result is that students are able to interact, record data and share ideas more quickly than in the traditional classroom.

1. Introduction

Education creates interaction between the student and the world. We advocate that successful educational technology fuel educational collaboration. When the student is challenged by the lack of direct contact with his teacher and peers, modern technology offers new forms of communication to break down traditional barriers to successful education.

The rapidly evolving nature of education in the United States and elsewhere poses significant challenges to educators. Research has consistently shown that two-way communication between teacher and student can significantly enhance learning rates and overall student success [1]. Similarly, interactions between students can enhance peer to peer discovery, problem solving, and knowledge acquisition. However, increasing class sizes, particularly in technical fields, 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.

At the University of Illinois at Urbana-Champaign (UIUC), we are developing a software tool known as e-Fuzion that allows students and instructors to communicate in real time via wireless networking. During class, students can interact with the instructor(s) via a message server, allowing them to ask questions or request clarification without interrupting the flow of the lecture. e-Fuzion also provides an array of facilities that support integration of "active learning" exercises into large lecture settings. These exercises allow students opportunities to use material covered in the lecture immediately; they also provide the instructor with real-time feedback indicating student understanding of the material being presented. This ability allows the instructor the fluidity to re-emphasize the most challenging material, while simultaneously reducing the amount of time spent on simpler concepts.

Research in pervasive computing affords us the opportunity to investigate new paradigms for learning, where dependencies on temporal and spatial factors are rendered obsolete. When integrated with e-Fuzion, the functionality of additional technologies in an educational setting increases vastly. The result is a significant reduction in cost and a commensurate increase in the effectiveness of instruction.

2. e-Fuzion

In an e-Fuzion learning environment, instructors, students and teaching assistants comprise a team dedicated to learning [2]. In large lecture classes, the faculty member uses the presentation tools that e-Fuzion provides to annotate prepared slides with notes and examples. These slides are immediately transmitted over a wireless network to the students' computing devices. Students can use the same tools to make personal notes, which can be archived for later reference. To foster collaboration, e-Fuzion

incorporates a unique "graphical newsgroup" that encourages and facilitates communication among students and with faculty without time constraints. Teaching assistants monitoring the newsgroup during class can signal the lecturer when a particularly interesting or frequent question is raised. In turn, the faculty member can address that concern immediately. The graphical capabilities of e-Fuzion make possible the direct incorporation of figures from a presentation, greatly increasing the flexibility of the class. To enhance the clarity of such a response, teaching assistants can also illustrate their response with examples derived from the lecture. Students can simultaneously absorb content from the lecture slides and use it to post or answer questions. This interface allows students to work with core concepts while providing the instructor with an instant gauge of student comprehension.

A study of e-Fuzion's effectiveness at enhancing learning was conducted in 2002 [3]. For this study, students in a chosen Computer Science course were issued laptop computers with wireless networking capability. They were expected to bring these units to class in order to have access to the e-Fuzion software. Figure 1 illustrates this scenario.

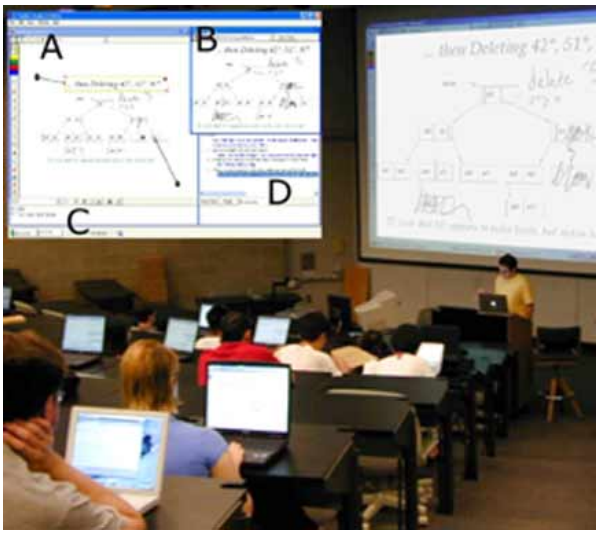

Figure 1: Student's view of e-Fuzion (upper left). Areas include: instructors slides and notes (B), student's clipboard (A), student notes (C), and class shared space (D)

The results of this study conclusively showed that use of e-Fuzion 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 laptop computers in a traditional classroom environment. Students were "unhappy" with the size and weight of the devices; the standard keyboard/screen configuration of a laptop also interfered with the student's ability to see the instructor, particularly in large, auditorium-style, lecture halls. For these reasons, we are eager to investigate how more portable, specialized devices might better meet the needs of our students.

3. Problems with Conventional Technology

The Computer Science Department at the University of Illinois uses much conventional information technology to enhance learning and offer distance learning degrees and courses. The department has used web and video streaming technologies for asynchronous education and distance-learning since 1995 and uses bulletin boards, news, grades and on-line testing to enhance its courses. The University of Illinois has been an early adopter of computer technology for education.

Starting in 1959, before the advent of the web, the PLATO system [4] was used to deliver instruction on campus. Online chat and bulletin-board notes features were added in the early 1970s. In 1975, Control Data Corporation (CDC) established PLATO-IV as a commercial educational product that, by 1985, had established systems in over 100 campuses around the globe. Later versions of the notes system became popular communication mechanisms for student interactions including Lotus Notes, a system created by alumnus Ray Ozzie [5]. The PLATO system is an example of using a client-server computer technology for education. The client-server approach implements most current web-based educational communication and interaction systems.

Modern electronic web, chat, newsgroups and email systems are examples of distributed educational information technologies that have their origins in a workstation/mainframe perspective of computing. This capability allows local and remote students to communicate outside of fixed office hours and provides both synchronous and asynchronous forms of distance learning. The hierarchical structure offers control of the educational materials, security, information propagation, testing, and evaluation.

However, the recent arrival of ubiquitous computing introduces a non-invasive, "natural", notion of human-computer interaction. New input and output devices encourage communication based on handwriting, speech, and gestures. Computers have become small and mobile as exemplified by the pervasive cellular telephone. Users expect

"anytime/anywhere" communication with information systems and enjoy a one-to-many relationship with the systems they use. Peer to peer computing has come to challenge many of the client/server conventions used in existing systems and allows control to become decentralized. Last, with the presence of so many computers and sensors in a modern environment, researchers have turned their attention to developing systems that are context-aware. Location, temperature, air-quality, and ambient noise level are some of the sensors that can augment knowledge about the classroom and students.

In much the same way that cellular telephones have changed telecommunications, we expect that ubiquitous computing will change educational information technology. Based on our experiments with e-Fuzion, we focus our research on improving the interactions between teachers and students in a ubiquitous computing environment.

4. Gaia and Active Spaces

Gaia is a distributed meta-operating system, designed to facilitate the creation and operation of active spaces. Among the services provided by Gaia are: component management, resource discovery, location discovery, and security [6]. By utilizing a layered architecture Gaia allows the abstraction of physical spaces and the various entities contained within it as a single programmable entity. Figure 2 illustrates the layered Gaia infrastructure. The Application Framework utilizes the Unified Object Bus (UOB), a system that provides common tools for managing components [7]. This system provides an interface on a device to support Gaia and has been implemented on devices other than traditional computers, such as Pocket PC-based PDA's.

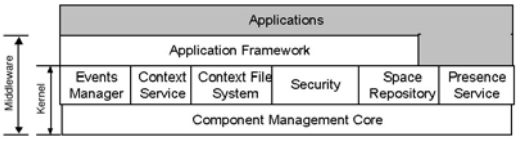

Figure 2: Gaia layered architecture

Full-scale adoption of active spaces in a pedagogical environment requires support for resource stripped devices, such as most "mobile" phones. As they stand, these are not sufficiently powerful to run the UOB. For such situations, we provide a proxy service (figure 3), that allows devices with limited resources to communicate with Gaia.

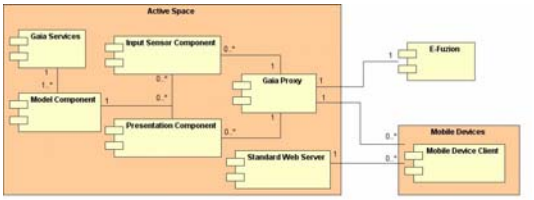

Figure 3: Gaia mobility design

5. Active Space Collaboration

The integration of Active Spaces and e-Fuzion will foster the development of new tools and strategies designed for educational collaboration. Services offered by mobile smart phones, (data, telephony, text messaging and pictography) are well-suited for such interaction. By leveraging these features through our middleware, development of new applications designed to enhance the learning experience will be possible.

5.1 System Design

To accommodate mobile clients, we enlist the services of Gaia to handle the computationally and resource-intensive tasks. In this context, Gaia serves both as a medium for e-Fuzion to communicate with smart devices and as a registry of device information. Information stored in the device registry will be available for future applications that will make full use of a mobile device. For example, this system can correlate a phone number to a specific mobile client so that a text message may be sent to notify the user. Alternatively, a TA can reference this information and respond to the student over the phone.

Figure 4 illustrates the design topology of the extended system. The area in the dotted rectangle represents the e-Fuzion architecture. The e-Fuzion system provides the core frameworks necessary to push the displayed information and handwritten annotations from instructor to the student devices. The Gaia and e-Fuzion proxies work in cooperation to manage session data.

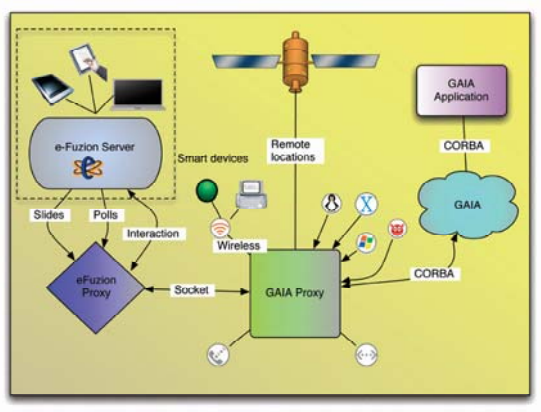

Figure 4: System architecture

5.2 Gaia Proxy Architecture and Design

The Gaia Proxy enables devices unable to run the Unified Object Bus to interact with applications running in a Gaia-enabled active space. This is done by providing a level of indirection between the devices and relevant Gaia services. Gaia applications are essentially sets of components that allow applications to become adaptive to the environment. Since these devices are unable to access the UOB directly, the Gaia Proxy must perform the requests on behalf of these devices. To reduce the complexity of the target device software, and in order to accommodate stateless thin clients, we must shift as much work as possible to the Gaia Proxy Service; which in turn may encode and broadcast data to the mobile devices.

The Gaia Proxy provides the bridge between e-Fuzion and Gaia for bidirectional communication and exchange of information. For example, as an instructor traverses through their presentation, the e-Fuzion Proxy transmits messages containing the slide information to the Gaia Proxy, which in turn, triggers an event on the Gaia proxy notifying the eScribble Gaia application. A new application state is then sent to the mobile clients. Figure 5 illustrates this protocol.

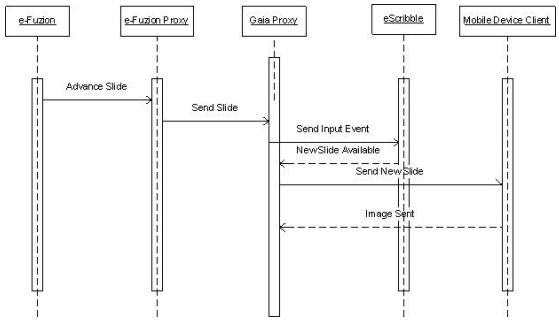

Figure 5: Slide sequence diagram

A similar series of events occur whenever a new quiz or poll is made available. This mechanism can be used to support a variety of e-Fuzion features on devices stripped of resources, as well as provide the protocols necessary to support more advanced uses of e-Fuzion. The conduit between e-Fuzion and Gaia is also used by the e-Scribble Gaia application to report information to e-Fuzion when client events occur. One example is the transmission of data representing the results of an instant poll or quiz; the aggregated data is sent to e-Fuzion through the Gaia Proxy.

5.3 Accommodating Thin Clients

The thin client applications connect to the Gaia proxy and request use of the eScribble application. Upon successful registration, the device provides the server with necessary information about the capabilities available. (The phone number provides a useful naming scheme.) Bidirectional communication is afforded through thin Java or Brew-like clients. Finally, the software awaits messages and updates the view of the application accordingly. The messages are formatted to make efficient use of the resource available on the device. For example, requests are made through flexible and adaptable information identification such as XML and an instructor's annotated slide can be transmitted to a device as an image with the appropriate resolution.

6. Future Direction

The expansion of e-Fuzion into the ubiquitous domain helps to foster the free exchange of ideas. We intend to investigate the feasibility of using specialized services to enhance the quality of learning with mobile devices. One scenario will be the expansion of the e-Fuzion graphical newsgroup to leverage the functionalities available in portable devices. For example, camera phones and recording devices can enhance clarity in student postings by allowing them to express abstract concepts through flexible multi-modal communication.

Another application to enhance educational exchange is pervasive groupware. Short Message Service (SMS) and Bluetooth technologies can facilitate group interaction by providing a context-aware environment with shared calendars, documents and events, anytime & anywhere. Students benefit from additional synchronous communications with classmates via an active notification system over multimedia messaging (MMS).

Although small devices have limited power to operate, in the future we see our system sending alerts

to a student device so that the system only uses power on an as-needed basis. Using the Java 2 Micro Edition Mobile Information Device Profile standard (MIDP2), a phone can launch a program when the network sends a MIDP push message to a mobile device. This allows our software to handle this asynchronous message without constantly occupying the screen and draining the device's battery.

7. Conclusion

The advancement of technology affords us an opportunity to expand the capabilities of education systems through active space collaboration. e-Fuzion minimizes the barriers associated with oversized classrooms devoid of interaction, while Gaia reduces temporal and spatial barriers which inhibit effective team work. Once these impediments are addressed, we believe ubiquitous computing will allow for a truly collaborative anywhere/anytime environment for enhanced learning.

8. References

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