SMEO: A platform for Smart Classrooms with Enhanced Information Access and Operations Automation

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Abstract. This paper explores the area of creating smart spaces using mobile Internet devices to develop intelligent classrooms. We propose a suite of applications that leverage the recent progress made in the domains of mobile computers and information access, resulting in a richer classroom experience where knowledge is dispensed with greater efficiency while also making it possible to access it efficiently from the Internet as well as peers. We attempt to achieve this by introducing novel means of classroom teaching and management and an intelligent information access system while harnessing the computational capabilities of mobile Internet devices. Though the current work is still in progress, this paper elaborates on our attempts in reducing the gap between technological progress in various domains and the existing pedagogy.

Key words: Smart Spaces, Intelligent Classrooms, Teaching Methodologies, Information Access

1 Introduction

The last couple of years have seen advent of a number of novel and powerful mobile computers which have revolutionized the mobile market. A couple of years back mobile devices had low processing power, limited multimedia functionalities, poor web connectivity, and restricted memory and storage capacities, leaving a wide gap between the capabilities of a mobile device and that of a desktop PC. In recent times, handy mobile Internet devices with higher processing powers and availability of a large array of features has largely bridged this gap for a number of functionalities, opening new vistas for application of these capabilities.

At the same time, rapid growth of Internet has resulted in an unprecedented increase of content on the web. Availability of large amounts of information on the web resulted in a pressing need for development of 'Information Access' systems that would assist users with an information need in identifying relevant information and producing it in a concise form. This led to research and development in various modes of Information Access such as Information Retrieval, Text Categorization, Text Summarization, among others. Over the years, these generic systems have matured considerably leading to opportunities for their application in new scenarios and systems.

While there has been remarkable growth in technology, the classroom pedagogy has been largely oblivious of these technological gains, with the instructors still employing boards and presentations while the students take notes on paper notebooks. In the current teaching methodology, a students learning is constrained by the knowledge of the instructor while the opportunities for learning from peers remain largely untapped. Also, the vast pool of knowledge that exists on the web is not effectively consumed because it is not available on the go, coupled with issues of retrieving the needed information in a precise and swift manner. In this work we attempt to address the stated issues by introducing smart mobile Internet devices in a classroom environment where efficient classroom teaching and management, and intelligent information access can be provided using the 3Cs of the device namely, context, communication and computation. We next elaborate on the 3Cs of the device, claiming that their presence can be utilized to harness the technological growth in enhancing learning.

The context of classroom environment helps us in knowing that only documents that are academic in nature should constitute the repository. Moreover, knowledge about the topic to be discussed in next class can be taken as a factor to determine the temporal importance and relevance of a document. In fact, the context of which user makes a query is used as a parameter to customize the choice and ordering of results.

Communication capabilities of the device are used extensively for the project. To cite a few examples, it is used to connect devices over remote framebuffer protocol using VNC. Similarly, course content sharing both in real time as well as through archive happens over the network.

From the computation perspective, the device's touchscreen capability allows the instructor to annotate over the slides during the presentation, students to view slides, make notes and pass their queries vocally to the instructor, making it particularly useful when they are remotely connected. In future, with improved Optical Character Recognition (OCR) capabilities, annotations will be converted into text, thus making it searchable.

Recent years have seen a number of attempts to technologize the classroom pedagogy. Some of these systems, like the closed source Blackboard[6] system, have been commercially used in niche classroom management market, providing functionalities for course and content management system. Classroom presenter [1], [2] is an open source research oriented system largely focusing on distance learning. It also provides functionalities for lecture archiving, including voice and annotations. One drawback of this system is that it does not work on mobile devices. Ubiquitous [3], is a system that attempts to get over this drawback by using platform independent web-based front end while still depending on classroom presenter in the back end. DyKnow [4], another closed source commercial product, in addition to classroom teaching functionalities, also provides the instructor with ability to monitor student devices. Online conferencing systems like Dimdim[7] are also occasionally used in classrooms providing functionalities like collaborative document viewing and annotations with voice streaming.

In this paper we propose SMEO, a system that in addition to classroom teaching and management using mobile devices also provides functionalities for smart information access. While, the classroom teaching and management module provides tools to stream and archive lecture, and to manage attendance, classroom facilities, queries, and quizzes, the most unique contribution of this work is integration of smart information access techniques which to the best of our knowledge is the first such attempt. Focusing on contextual personalized search, summarization and collaborative learning, it aims at providing improved means of learning in a classroom environment.

While the current work is still under progress, we present the inspiration for this work along with it current status, besides stating the goals of this work. The remainder of this paper is organized as follows: in Section 2 we discuss the architectural setup that we used. We follow this with a broad outline of the proposed platform in Section 3. Section 4 elaborates our ideas on improving classroom teaching and management using the mobile computer devices while Section 5 expands on how intelligent information access techniques could enhance learning. Finally, in Section 6 we state the conclusions drawn from this work along with suggestions for future improvements.

2 Architecture

SMEO requires the following infrastructure to be present in the classroom:

1. A Linux server for handling the classroom teaching and management module
2. A Linux server for running the information access module
3. A projector
4. High speed Wi-Fi
5. Internet connection
6. A mobile computer for the instructor

[6] `http://www.blackboard.com`
[7] `http://www.dimdim.com`

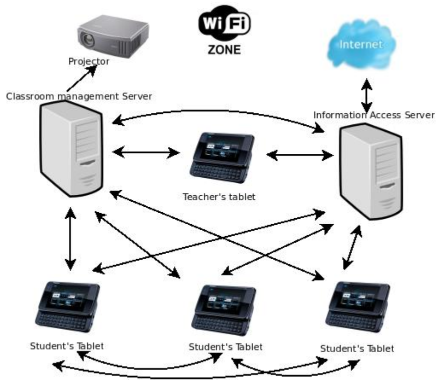

Fig. 1. Architectural Setup

7. A mobile computer for each student

As shown in Fig. 1 the classroom teaching and management Linux server is directly connected to the projector, so the slides which the instructor wants to project on to the projector are kept on this server. But the instructor views, controls and annotates the slides from the mobile computer which is connected to this server through VNC which shows the remote computer's display on the local computer which is the mobile computer in this case. All the communication between the instructor and student mobile computers, whether it is student queries to the instructor or conducting of quiz by the instructor, happens through the classroom teaching and management server. The information access module, on the other hand is responsible for running all search related jobs, such as crawling, indexing, maintenance of profiles, among others. This should be accessible to the devices and connected to the Internet. Both the servers are internally connected because sharing of information among them, is required at various steps, such as extending the operations of search and summarization to the course content.

3 The Application

SMEO is a platform for creating smart spaces in a classroom environment providing a suite of applications on high performance mobile Internet devices that can broadly be categorized into - Classroom teaching and management: focusing on smarter delivery of lectures and Intelligent information access: focusing on smarter means to access information. We attempt to enhance classroom learning by providing relevant applications from both these class of applications through a simple interface to the instructor and the students. In the following sections we elaborate on the methodology and work-flow of each of these applications. Because of the large number of tools and limited space we show the screenshots of only few of these applications.

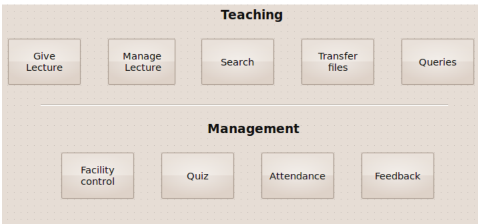

Fig. 2. Instructor's Interface of Applications

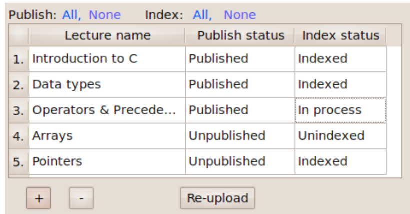

Fig. 3. Manage Lecture Display

The set of applications and the underlying functionalities to which an individual has access, varies according to their privileges, depending on whether the individual accessing the application is an instructor or a student. The start interface for the instructor is shown in Fig. 2. Student interface, though similar, is not shown because of paucity of space.

4 Classroom Teaching and Management

Once SMEO authenticates a user through a pre-registered username and password, the classroom teaching and management module provides interface for all interactions between the user and the application. There exist separate interfaces for instructors and students and corresponding to their roles and privileges a set of applications are displayed.

While we discuss most applications provided by SMEO (from instructor's perspective as well as student's perspective) in this section, we devote a separate section for the information access functionalities because of the uniqueness of its applicability in a classroom environment.

4.1 Lecture Delivery/Attendance

This module allows the instructor to use the mobile computer to navigate the slides and annotate over them. The lecture is streamed to the students in real time and is also archived so that students can download it for offline use. Students can also make private annotations which can serve as their notes.

Before the teacher starts the lecture, he needs to upload the presentation to the classroom management server. The system ensures that the instructor has filled meta-fields of title and keywords, which are required by the information access module, before uploading. Fig. 3 shows the screen for managing lectures. The instructor can either add or remove a lecture, publish (making it accessible to students) or unpublish it, or request retrieval and indexing of documents related to the current lecture. As soon as lecture is published, crawling and indexing of documents related to the topics to be covered, is started. Thus, an instructor is required to publish the lecture content, a couple of hours before the lecture to allow crawling and indexing of relevant documents, ahead of the lecture, enabling the availability of updated information access applications.

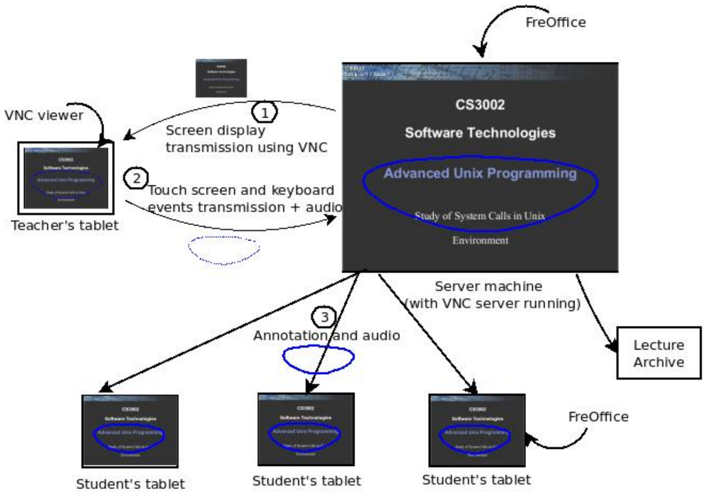

Fig. 4. Lecture streaming

When the teacher wants to take a lecture, he connects to the server using VNC (Virtual Network Computing) system. Next, controlling the server through VNC, instructor opens the presentation on the server with FreOffice (koffice port for Maemo). The original version of FreOffice did not have the capability to annotate but the extended version on which we are working, allows annotations on slides. The transmission of server's display, annotations and audio over the network is explained in Fig. 4. Through VNC, when the instructor annotates the slides by scribbling over them using the stylus, each annotation stroke is stored as a separate file. The directory in which the annotation stroke files are created is kept in sync with a directory on student side using rsync. Also, instructor's voice is streamed to student devices, besides being recorded for archival purposes.

On the server side, an XML file is maintained, which stores the names of the annotation stroke files and the time stamps of the annotation stroke with the associated slide number. When the lecture finishes, this XML file and the annotation stroke files are pushed to the archive so that students or the instructor can download them for offline use. When working in offline mode, our extended FreOffice parses the XML containing the time stamps and the annotation stroke file names, and displays them over the slides in a time sequence.

Students are also allowed to make their own annotations which can be shared among peers, thus allowing community sharing of notes. For reducing clutter on the displayed presentation, students can switch on/off one or more of the annotation layers. If a student only wants to view the instructor's annotations with the slides, he can simply connect to the VNC server running on the server machine in 'view only mode'. This can be done anytime during the course of a lecture. This allows a student to observe activities on the display of the server (which is also displayed on the projector screen) by running VNC server in 'view-only' mode.

Note: The tool described in this Section can also be used by the instructor to correct assignments by making annotations or by recording vocal comments, which are sent to students once the correction is done. This makes the assignment evaluation more interactive and swift.

4.2 Intelligent Information Access

This is a web based suite of tools for efficiently accessing contextual information available on the web along with that generated in the course. It has tools for contextual personalized search, summarization and collaborative learning, enabling access to relevant information in a well presented format. While it provides an interface for quick search and accessing other 'information access' services to students, the instructor's interface is supplemented with options to specify indexing process, corresponding 'seed topics', besides other functionalities. Services provided by the information access suite are further elaborated in Section 5.

4.3 Classroom Question Answering

This application provides an efficient question answering mechanism for the classroom. During the lecture, students can send requests to ask queries. These requests are queued on the server. The instructor can look at the set of queued queries and approve acceptance of one request at a time.

When a request is approved, a message "Ask your question!" is flashed on the referred student's device. When the question is asked, the voice is forwarded to all the students devices which are part of that course. This enables the discussion in the class to be audible, making it suitable for large classes to be handled well, as many times the queries as well as the responses are very useful learning experience for the listeners. Since we have the voice channel open between several devices, it makes the overall session audible to all the students connected to the lecture.

4.4 Design/Attempt Quiz

This module helps the instructor to create a password protected quiz and share it with the students. It also allows the student to open the quiz, answer it using a user friendly quiz form and view the grades once it is graded.

An instructor can create a quiz using the 'quiz creator', either on laptop or a mobile computer. It creates an encrypted file containing the questions and the answers in an XML format, which is uploaded on the server and a start time for the quiz is announced. The encryption key is known only to the instructor. The instructor then uploads this file on to the server and announces a start time for the quiz. Students download the quiz file at their convenience and at the start time, the key is made public. This key needs to be fed to the quiz client for accessing the quiz. The quiz client decrypts the file using the key, and creates a user friendly form to allow the students to answer the quiz and submit the answers to the server. It allows the students to mark certain questions for review, filter questions and search questions. Another thing to note is that this quiz XML follows Moodle quiz XML schema so it can also be used with Moodle [5]. At the finishing of the quiz duration the grades are calculated by the client, sent to the server for archiving and displayed to the student on his mobile computer.

4.5 Classroom Feedback

One unique feature of our project is the feedback system. It allows the instructor to have real-time feedback on how many students are understanding the presentation. This feedback is integrated with our extended FreOffice. It allows the student to rate any particular slide for its difficulty. This gives the instructor a real-time feedback if students are finding some topic difficult to comprehend. Students also have an option to give feedback for the whole lecture. The difficulty rating is kept anonymous, but for the lecture feedback student has a choice to reveal his identity.

4.6 Facility Control

This module enhances classroom comfort by controlling classroom facilities, like fans, lights, A/Cs, projectors, window films, and dimmable lights, automatically or by minimal manual intervention. We are working on a building automation gateway that connects with any building automation backends which can work with known building automation protocols such as LonTalk, or bacnet, and can connect to various facilities through relays, Wi-Fi, Zigbee [6] or IR.

The gateway, which is an embedded server, stores the coordinates of available facilities and different mode settings for the classroom in an XML file which the instructor can download. Using the XML file, the instructor side application constructs a map of the classroom, showing the facilities and their on/off status. Clicking on any of the buttons in the map switches the appliance on or off and also changes the color of the button. The instructor can also select one of the various modes, “Presentation” mode, “All lights off” mode, etc, to switch on/off a number of appliances at a single click. The gateway also has an access control mechanism which does not allow anybody other than the instructor to control the facilities.

For making the classroom energy efficient, the gateway dynamically controls the operating parameters based on the current needs and also uses feed forward and feedback controls. The devices help in getting a feedback in terms of number of people present and their comfort requirements which helps the system to optimize the energy consumption while still maintaining the comfort requirements. Methods such as demand based fresh air, enthalpy based control, etc are also used.

4.7 Remote Classroom Presence

Another interesting feature of the system is that the students or the instructors can attend or give a lecture from any corner of the world. They just need a working Internet connection on their mobile computers which can connect them to the classroom over a Virtual Private Network. This makes all the above mentioned tools accessible to them. This feature can also allow the subject matter experts to give lectures remotely or even take a whole course remotely. Similarly, students from different universities can be given access to attend the lectures remotely.

4.8 Classroom Attendance

This is a simple application that allows the instructor to know the number of students connected to the server, either remotely or locally.

5 Intelligent Information Access

The most unique aspect of this project is the incorporation of 'Intelligent Information Access' in a classroom environment and its integration with classroom management modules. By 'Intelligent Information Access' we imply the ability to retrieve, extract and access the information as needed in the context of a classroom. We provide the stated capability through a wide-range of information access techniques, primarily focused on contextual search, personalization and summarization technologies while also exploring the domain of collaborative learning. We next elaborate on each of these techniques along with a discussion on their adaptation to the classroom environment.

5.1 Corpus Building & Contextual Search

By contextual search we imply that the system is aware that it is catering to queries given in a classroom environment and hence has to produce results that are academic in nature. Moreover, the system also takes into consideration the courses currently being studied by a student while producing search results for a user query. In fact, it attempts to provide results that are contextually more relevant to the topics covered in recent classes. To achieve this we used a two-pronged approach of selectively constructing a corpus of relevant documents and its deep-indexing which is complemented by personalization (explained in section 5.2) of results. This module also builds the corpus by indexing relevant documents retrieved from the web along with course content stored in classroom management folder, making it searchable.

The first step to contextual search is corpus building. It is depicted in Fig. 5 and works in the following manner: as mentioned in Section 4.1, with each lecture presentation, the instructor must fill the meta-fields of title and keywords. These keywords serve as the 'seed topics' for retrieving other related topics. These

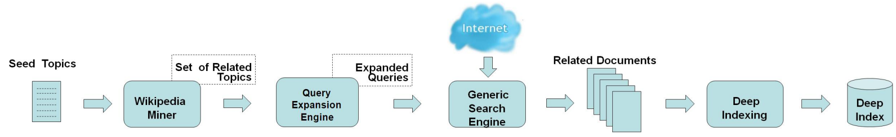

Fig. 5. Contextual Search: Flow Diagram

topics are given to Wikipedia Miner [7], a toolkit for navigating and making use of the structure and content of Wikipedia, to retrieve semantically related topics. A combination of 'seed' and related topics, serving as queries, are submitted to generic search engines and top-hits are crawled. These documents are then deeply indexed for classroom consumption. By deep-indexing we imply that the index contains much richer information than a conventional inverted index, such as named entities, other semantic entities and meta-information like the course and lecture associated with it. This index can now be searched and the search returns much more contextually relevant results.

5.2 Personalization

Personalization aims to sort search results based on the specific needs and interests of individuals, instead of producing same results to anyone giving an identical query. Personalization of search tools adds an extra step to the search process. Thus, the query is first matched against the corpus of documents to retrieve relevant results. This is followed by matching results with user profiles to sort the results according to user preferences. The profile of a user contains explicitly gathered information such as the content of courses done in the past and those that are currently being pursued along with implicitly gathered dynamic information such as search history consisting of queries and the corresponding hits. This information is used by the system to customize the search results so as to produce more relevant results for a user. We also attempt at extending personalization to a group level because individuals with similar profiles might benefit from the search history of each other. Thus we also attempt at maintaining group profiles and customizing results for users with similar profiles at a group level, as well.

5.3 Summarization

Document summarization is defined as an automatic procedure aimed at extraction of information from multiple text documents. It is the process of condensing text information to its most essential facts. Thus, a well composed and coherent summary is a solution for information overload. In the current work, while we do not make claims about improving the document summarization algorithms, we worked on employing existing summarization systems in a smart way. While we used [8] in this work, any other high precision generic multi document summarizer can be substituted as a replacement to our summarizer. Besides providing an interface for conventional multi-document summarization we also provided two novel manifestations of text summarizers. In the first of these, a user expresses information need in the form of a query for which the contextual search engine displays results. The user can seek a summary of any subset of these results by selecting check-boxes provided next to the results and clicking on the summarize button. In the second case a user expresses information need in the form of a set of questions, and the system produces a single text as the summarized version of a single or multiple documents containing the relevant information. That is, given a user's information need the system identifies a set of relevant documents from the corpus and further creates, from the document set, a summary which answers the expressed information need.

5.4 Collaborative Learning

In this module we explored group learning aspects wherein knowledge acquired by one student could be utilized by the student community using the system. In the current work we introduced some simple yet effective features for collaborative learning. For example, we took explicit (in the form of link recommendation) and implicit (in the form of page hits for a given query) feedback from the search module to improve the results. We also collected statistics such as the most queried terms and the most viewed documents for each course, over different time periods, to make recommendations. We also had a feature for collaborative bookmarking and their tagging. Making this information searchable came handy while looking for links pertaining to topics identified by tags. We also attempted to make the annotations made by students, searchable. This would have helped students in getting better insights to the text mentioned in a slide utilizing the comprehension of their peers. Unfortunately, this was hampered by the limited OCR capabilities of the mobile computers that we used in our work. Future devices, with improved OCR capabilities should make it feasible to convert annotations into text which can easily be made searchable, thereby greatly enhancing the scope of collaborative learning. We believe that we only touched the surface of group learning and there is considerable scope of enhanced learning in this domain.

6 Conclusion & Future Work

We believe that the system which we have described is yet another step in the direction of digitizing the classrooms. Since the whole system is open source it can be extended to support the future needs of the classrooms.

There still remain a number of issues and challenges to overcome in the attempt to digitize classrooms. While technical advances will happen and newer functionalities and features will be introduced, probably the greatest challenge is the introduction and acceptance of such means of teaching and learning in the classroom setup. But, we should remember that it was not too long ago that the community was apprehensive about the success of teaching through presentation slides but now their use is widespread. While presentation slides only made classroom teaching more structured and orderly, development of classrooms on our lines might influence and enhance learning more drastically. We believe that further experiments and evaluative studies are required in this direction to ascertain their influence.

In the current work we proposed a prototype for improving and enhancing classroom teaching and learning, there still remain some critical issues that need to be worked on, before the success of current work can be ensured. As the next step, we need to work on issues such as ensuring confidentiality and reliability of the system while identifying alternative means of working, in cases of device failures. We also need to employ the system in an actual classroom environment to determine the resource requirements of the system and to resolve issues of scalability, should it arise.

As the mobile devices become more powerful and technologies like OCR help replace pen and paper with digital pen (stylus) and digit paper (touch screen) we hope that the classrooms of tomorrow, in addition to being user friendly, environmental friendly and energy efficient, will be fully digital, remotely accessible and will have efficient techniques for retrieving and presenting relevant information.

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