Enhancing Engineering Educational Using Virtual Lab Technology

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Abstract - **Providing Engineering lab equipments at each and every corner of this world is not possible but it is possible to provide a software! Virtual Lab technology adapts this concept and provides education to as much remote as possible locations. Virtual Lab is an Embedded Android Mobile Application that interfaces with the real physical lab equipments and makes it possible to conduct experiments from remote location. Virtual Lab is connected to main Lab from a Remote lab using Internet. It is also capable of connecting using Bluetooth, provided Virtual Lab application is running in a device which is near to Lab equipment. It takes input from the user and sends corresponding signals to the hardware using HTTP protocol. Students can perform their experiments on their Android device virtually and see the live result which is carried out in the main central lab using high quality video streaming. Experiments are preloaded in the application and new experiments can be loaded by updating the application. This application is connected to a web-server that in turn connects it to a loud database, which provides study materials for the students and faculties any time.**

Keywords – Virtual Lab; Visual Editor; Android; Java; Sensor-network; Bluetooth; Wi-Fi; Web-server; Client-server communication; HTTP request/response; FTP protocol.

I. INTRODUCTION

The rapid development in mobile, wireless, and sensor technologies provide new possibilities for augmented learning activities. These technology-enhanced learning activities can be spatially distributed and incorporate different physical and environmental sensory data [1]. In addition, sensor-based technology has provided new perspectives about how learning activities can be embedded in different settings and across contexts [2].

However, despite these technological advancements many challenges still remain related to the integration of different technological resources for use in broader educational scenarios. The efforts described in this paper are related to our ongoing research that explores the challenges related to the technological integration of different devices and sensors to support science inquiry learning. Thus, the main research question addressed in this paper can be formulated as follows: *How mobile, web and sensory technologies could be integrated to support science inquiry learning activities in the classroom and in outdoors settings?*

This paper focuses on our design and technical efforts in relation to system and software development to support science inquiry learning by means of efficient use of virtual lab with the help of different portable sensory devices. The paper is organized as follows: section two presents a brief background relating the importance of context in supporting learning and technology design. In order to position our work, section three provides an overview of related research contributions closely aligned with our current efforts. Afterwards, we introduce our proposed system architecture that guided the design and technological development in this research effort. This overview is followed by a description of a learning activity experiment in which the proposed system was used to provide support for science inquiry activities with case study. The paper ends with a discussion and an outline of our future work.

II. BACKGROUND

The notion of context and its implications for mobile learning has gained a lot of attention among members of the research community in the last years. A recent study conducted by Frohberg and colleagues emphasize how context can be used for the classification of mobile learning [3]. One of the main conclusions of their study was that "*mobile learning can best provide support for learning in context.*"

In our particular case, this statement supports the idea that mobile learning needs to be designed to promote active science inquiry learning across different educational situations. Mobile probes can augment learner investigations with real-time geo-positioned data and visualizations, which may increase students' engagement, enabling them to conduct scientific inquiries and analyses in novel ways. One innovative aspect of these new learning landscapes is the combination of learning activities to be conducted across different educational contexts such as schools, nature and science centers/museums.

This indoor-outdoor integration of mobile computing has expanded the important feature of *context* *awareness* into learning environments. From an educational viewpoint, *context awareness* refers to how the pedagogical flow and content in the different learning activities needs to be aware of the situations in which the learners are (e.g., geo-location, proximity to people and objects). From a technological perspective, context can be regarded as any information that illustrates the situation of a group of learners, including location, time, activities, and their preferences [4]. The crucial factor for context awareness is the possibility of capturing this broad range of contextual attributes [5]. These characteristics combined together with sensors that provide additional information about the current physical environment can serve as a good basis to support new ways of interactions between the users and the environment and for the visualization of spatially referenced/distributed data [6]. In the following section, we describe some related projects that have addressed the issue of context awareness to support science learning.

Stanford Mobile Inquiry-based Learning Environment (SMILE) is basically an assessment/inquiry maker which allows students to quickly create own inquiries or homework items based on their own learning for the day [18]. AJDSP project designed for interfacing health related sensors [1, 2]. AJDSP interfaces sensors for measuring ECG and GSR for medical purposes. That application reads data from sensors and plot graph for corresponding data. There is a similar application available that can be used in medical projects [3]. J-DSP application is designed for educational purpose [4]. This application is used in the laboratories for teaching Digital Signal Processing to students.

In case of environmental studies, now-a-days many applications are being developed in the market to study environmental factors. One of them is used to measure temperature using mobile phone [5]. So these projects can be extended to create a global sensor network, which can be modified as per will at any instance of time just by changing the coding.

In computers Matlab is widely used for real-time sensor data acquisition and data processing [6]. Matlab can communicate with sensors and process data in real-time using Matlab code. But Matlab can only runs on computers and not on smart-phones and tablets. But if it becomes possible to combine structure of Matlab [6] and processing technique of AJDSP [1] [2], it is possible to do the same functions from a smart-phone.

Since 2002 the Computer Science Department of the University of Salerno has given a considerable effort in designing and implementing innovative educational laboratories or virtual lab for the Computer Science undergraduate courses. In 2004, the e-Class project, funded by the EU, focused the replacement of three heterogeneous laboratories equipped with over 50 multi-boot PCs with an integrated networked infrastructure which interconnected 350 workstations spanned over seven laboratories with 50 seats each. The e-Class infrastructure provided multi-OS (Windows/Linux) workstations with single sign-on, remote profiles, distributed storage areas, centralized management of fine-grained access control policies and remote deployment of applications as well as OS updates.

III. SYSTEM ARCHITECTURE

Virtual lab is the technology that is designed with a vision of combining all educational institutes and universities to provide education at all the corner of the world. Today most difficult challenge for providing education to all places of the world is the lack of lab equipments and education materials' availability. Our main focus in this technology is to rectify this situation as much as possible. Using mobile technology and its wide features can be utilized in fulfilling these approaches.

Virtual Lab is a mobile application consisting of four main entities and two user ends as shown in the figure. these entities are remote lab, well-equipped lab, web-server and cloud database. Two users are local faculty and senior faculty. There are two versions of this application. This application is different for students and faculty.

This section presents the overall system architecture, which includes an overview from a high level perspective to a low-level perspective of a set of hardware and software components. With reference to the deficiencies identified in the related work section and from several basic functional requirements identified during the design phase we have developed the system architecture illustrated in Figure 1.

The blocks are used to construct this architecture with the aim to provide some logical divisions of the resources in the system. The architecture organizes available resources into the following blocks: sensors, mobile devices, web server and database. It provides a complete lifecycle showing how data can be stored, exported, shared, and visualized. Our primary idea is to develop a generic architecture that can be used to support different aspects of inquiry science learning.

The most intense problem in providing education to remote areas is to provide education materials. The cloud database stores all the required study materials and lab manuals needed to teach high school and college students. User can easily access the study materials and simultaneously do lab experiments virtually which is explained late r in this paper. This application searches for required file which is the required material in formal, and then it sends the file ID to the web-server using HTTP request. Web-server processes the request and finds for particular file in the cloud database and returns the required file using FTP protocol to the mobile device. However, Web-server is not all times connected to mobile device. Every time, when a request arrives, it creates connection and after the operation, it closes the connection.

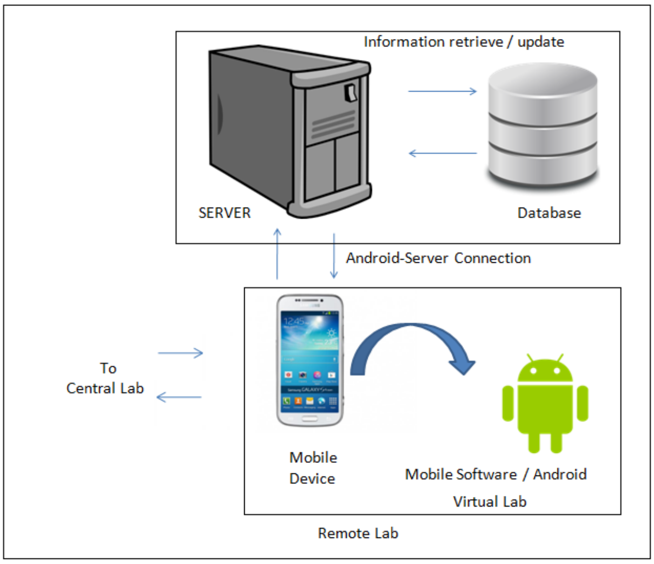


Figure 1 system architecture

A. System Architecture blocks description

• Context sensing is managed through the "*Sensors*" block of the proposed architecture (see Figure 1). The main functionality of this block is to comprehend user context aspects and different environmental data gathered during inquiry science learning activities.

• The "*Mobile Devices*" block is responsible for interfacing sensor devices and serializing their data streams into standard readable formats. This block is also important for annotation and tagging of different user generated content along with the environmental data. Furthermore, another functionality of this block is to transmit these data to the Server block of the architecture.

• The "*Server*" block is one of the most important components of our system, in which we store and organize content and contextual data. Moreover, this block offers extensibility capabilities by providing XML feeds to other systems. This block also offers web server capabilities including a database, content repositories, and web services. Earlier web-servers used in other mobile applications are static and can communicate with mobile application in pre-defined manner and in pre-defined data types [4][9]. We designed our web-server in much flexible way to communicate with any type of data. It works as a data exchanger and transmits whatever data it receives. Data which is received by web-server is also stored to a web-based database. It responds to the request dispatched by either mobile device or sensors. When sensor is communicating directly with server, it stores sensor data to database and when HTTP request comes from mobile device, it gives sensor readings to the mobile device with HTTP response.

The implementation of the proposed architecture required the development of several software tools and components. In order to test the validity of our system architecture and the functionality of its blocks, we have designed a prototype experiment to support inquiry-based learning activities in the field of Electrical Engineering Lab. A detailed description of this learning activity is presented in the following section.

IV. Learning Activity Description

When sensor connects with mobile devices, it gets three parameters (Serial Number, Vendor ID or Product ID) from the sensor and sends it to the server. It is here assumed that a web-based database has all sensor data according to these three parameters. So server sends these parameters to the database and requests the data frame. In response to this request, database sends the sensor data frame and this in turn sent to the mobile device. Here we assume that a kind of driver software is installed on mobile device for that particular sensor. So the application is ready to communicate with the sensor.

This application finds the name and address of sensor to be connected. Once device name is obtained, it is sent to the server. Server searches for the data frame for the sensor name received and returns back the sensor data frame. If no data is found, it sends null data. In this case a manual configuration is required. Once data frame is received, it will be connected to the sensor with the mobile device.

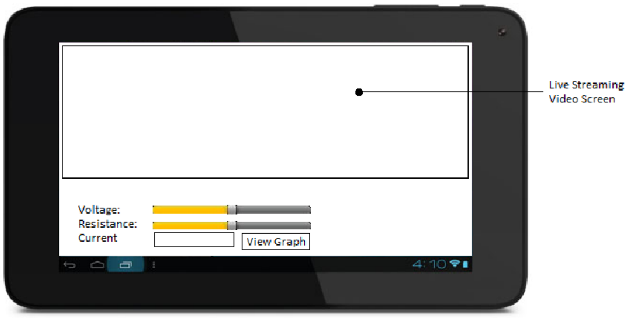
Visual editor is a feature provided by iMOSE application to create custom sensor networks. This visual editor basically consists of different icons which we call blocks. Each block represents a unique task. For example, a delay block will give a specific amount of delay in the program.

V. RESULTS

We consider that a virtual lab should support the execution of practical lessons in a way as faithful to reality as possible. Consequently, a virtual lab should be much more than a set of interactive objects. In the real world, the practical lessons performed in a lab use to be like a game, in which a set of targets must be achieved in a very specific order.

Accordingly, in our pedagogical approach, we aim to support one or more students carrying out a practical lesson by performing a sequence of steps or actions under the supervision of the system.

Guidance of the learning process is a very important aspect. When a student does not achieve a given target, there should be a mechanism to provide the student with hints and explanations about the reasons of his/her failures, or otherwise the student may get frustrated. For this purpose, we have created a Guiding Tutor software component that is capable of communicating with all the interactive objects involved in the learning environment, and that aims to provide a suitable guidance to the student. The guiding tutor is a key contribution to enhance the user's experience when compared to traditional non guided virtual labs. Figure 1 shows an example of Virtual Lab for Ohm's law as our case study.



Virtual Lab screen for Ohm's Law

- *Tutor guidance driven by dependencie:*

In order for the virtual lab to accomplish its mission, whenever the avatar of a student attempts to perform a relevant action over an object (touch, attach, drop, etc.), this object must inform of this action to the virtual lab. If the action is right, the lab will give permission to the object to execute the action. Otherwise, the virtual tutor will register the student's error and will choose between giving or denying the permission to execute the action according to the tutoring strategy specified in design time. In some cases, also specified by the tutoring strategy, it will provide a text message to the student informing him/her of his/her error or giving him/her a hint.

Our tutoring guidance relies on dependencies defined among the steps or actions that the student has to perform in the practice. The next enumeration shows the different types of dependencies that have been defined.

1) Previous Steps dependencies

The practical lesson is structured as a step by step process, requiring a positive evaluation of some previous steps to be allowed to start the next one. This evaluation can take the form of an explicit test or a check of well-done activities. At the end of a given step, the tutor system may provide the student with a message, indicating a positive evaluation of the current step and an invitation to proceed to the next step, or indicating a non-successful situation, because some required previous steps were not accomplished.

2) Order dependencies

In order to allow the student to perform some action, it may be required that some previous steps are executed in a given sequence, or in other cases, they can be completed in any order.

3) Time and duration dependencies

Some actions may require that a certain time has elapsed since a previous event. For example, in some cases, machine can be used only if it was turned on some time ago. If you try to use that machine before that time elapsed, the tutor will indicate that the machine is not available yet. Also, it can also be specified that an action expires after a certain period of time.

4) Action incompatibility (action context)

Usually, an action is considered as correct if a previous set of actions are executed but, in some cases, an action is considered correct if a previous action (or actions) is (are) not executed. For example, once the action of turning on a light has been executed, the room will be illuminated until a turn-off action is executed. A given activity that depends on the execution of a previous set of actions can additionally depend on not turning off the light during the execution of these actions. Even if other dependencies were respected, if the light was turned off, the result will not be achieved.

VI. FUTURE WORK

In this paper we have illustrated how our initial design ideas and technical efforts conducted in the virtual lab for Ohm's law can be used to create mobile sensor integration. Our system architecture enables off-the-shelf technologies to be used with the newly developed infrastructure by allowing multiple streams of data to be aggregated and analyzed for use in science learning activities. The system architecture and technical overview presented provide a future roadmap for our development with context sensing and awareness integrated with the smart phones, sensor-based technologies, and digital pens. One of the salient features of our software system is centered on the visualization of the sensory data. However, our current implementation still lacks the proper tools for user interaction with this data that can further support learning activities.

One issue that needs to be considered is the lack of open standards in education technology tools. Each of the devices has, to a large extent, a closed system approach that restricts the development of customized and integrated approaches advocated by the requirements. The scientific sensors system, the digital pen, and to some extent the smart phone required manual synchronization of data before we could provide the visualization tools. In addition, the data visualization tools had some trouble rendering the data in older versions of web browsers that are prevalent in the school IT systems. One of the fundamental technical challenges for the project is to explore how to create software and hardware solutions for educational uses that can be easily integrated into schools, making the potential of Science [21] accessible to high school students.

The next stage is to expand our approach to the mobile application, database design, and visualization tool by adding more automatic functionalities; we will take into consideration co-located and distributed collaboration. Given that our system architecture is still in the initial phase, we still need to develop applications (interfaces) for some of the building blocks of our architecture. Our aim is to develop our system toward fully-fledged context oriented architecture that transparently monitors contexts surrounding both clients and services in a given environment [22]. Furthermore, we will explore the possibilities for creating geo-visualization spaces to support collaboration in learning environments. Additionally, we will also explore how to integrate low-cost open source electronics to create sensor network grids for environmental data collection.

VII. CONCLUSION

We have designed a mechanism to develop virtual labs by using a free infrastructure for the development of virtual worlds. Our approach provides an inexpensive and flexible solution that can be easily configured to different practices and labs. The tutoring strategy is based on the definition of dependencies between actions, and it is very easily defined allowing even a human professor to specify it without any programming. This is a reusable software component that can be easily integrated into new virtual labs, providing the student with the necessary supervision and guidance during their learning process. The human professor is involved by providing timely information about the student's performance. In fact, the evaluations coming from our virtual labs can be combined with other grades, so that the professor can smoothly integrate virtual labs with other learning activities.

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