BRINGING SCIENCE AND ENGINEERING TO THE CLASSROOM USING MOBILE COMPUTING AND MODERN CYBERINFRASTRUCTURE

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Abstract: This paper reports on the creative educational and research program of MARIACHI (Mixed Apparatus for Radar Investigation of Cosmic-rays of High Ionization) at Stony Brook University, a unique endeavor that detects and studies atmospheric phenomena (lighting, meteors, or cosmic rays) by using a novel detection technique based on radar-like technology and traditional scintillator ground detectors. During the past and current academic year, our program has been effectively modernized and streamlined in both research and educational aspects with the implementation of mobile technologies by the use of TabletPCs and wireless data collection systems as well as emerging cyberinfrastructure based on dynamic services as wiki, blog, and Internet-based video conferencing.

1 INTRODUCTION

This paper reports on the latest efforts of the MARIACHI (Mixed Apparatus for Radar Investigation of Cosmic-rays of High Ionization) program (Takai, 2008) at Stony Brook University, a unique endeavor that detects and studies atmospheric phenomena (lighting, meteors, or cosmic rays) by using a novel detection technique based on radar-like technology and traditional scintillator ground detectors. The program provides intensive engineering, science research and educational experiences for students at all levels (high-school, undergraduate and graduate) working with a multidisciplinary team of scientists, engineers and educators (Bugallo et al., 2008).

Using atmospheric phenomena as vehicles to motivate research and educational activities, we develop innovative hands-on modules in physics, engineering and cyberinfrastructure based on a learning by doing philosophy with particular emphasis on radar technology (Bugallo et al., 2009). Students participate in research projects, seminars, and workshops, where they learn to use tools needed in MARIACHI. We create a natural chain of instruction where undergraduate and graduate students in the program participate in the instruction of high school students. To broaden the impact of the project, many activities are offered to a wide audience, with particular emphasis on traditionally underrepresented groups. The latter commitment is possible primarily due to the partnership of MARIACHI with the Stony Brook Center for Science and Mathematics Education (CESAME) (Bynum, 2008), an award winning science education organization, and the Women in Science and Engineering (WISE) program (Miller, 2008).

The current instruction of the educational activities offered by the MARIACHI team has been substantially improved by the use of mobile technologies in the form of TabletPCs. Our research and educational facility is a large laboratory with an area for theoretical lectures, a radar set-up, a scintillator ground site, and a data-acquisition room. Students participating in our offerings need to move from one place to another to take notes, develop different experiments, or attend seminars. The use of the TabletPCs has allowed for advancing the teaching/learning activities of our study program, and favor the joint use of facilities and expertise among not only students but also the rest of participants. Moreover, the physical separation of participants (high-schools, research sites, or classrooms) has required implementation of a reliable and secure data collection system and efficient tools for

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information exchange and communication. Emerging cyberinfrastructure based on grid technology has allowed for secure data exchange as well as for sharing of common knowledge and interactions among participants through dynamic services as wiki, blog, and Internet-based video conferencing. Our goal of bringing science research to classroom is achieved while students are exposed to cutting edge technology.

2 TEACHING & LEARNING MARIACHI

The science of MARIACHI requires the collection, processing and analysis of signals using radar-based technology and scintillator ground detector sites[1] (see Figure 1).

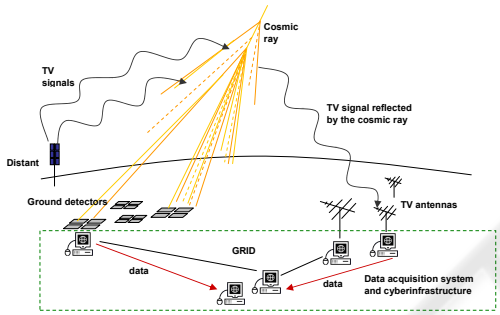

Figure 1: The MARIACHI experiment.

Through our educational offerings, students are not only exposed to the theoretical aspects of the project through regular lectures but they also experience all the practical phases of experiments with hands-on activities and by directly collaborating with physicists and engineers. The range and variety of activities is large and comprises from understanding concepts like frequency or cosmic rays to calibration of antennas (which are outside the laboratory) used for data collection, counting of events with ground detectors, collection and analysis of data, or reporting of results. Here we describe some of the main educational activities of the program.

2.1 Workshops

Through a one-week summer workshop and several one-day activities, high-school teachers and students learn about the main elements of MARIACHI and build scintillator ground detectors to be installed later on in their schools with the purpose of collaborating in the data collection and analysis (see Figure 2). The workshops are a combination of training, brainstorming, and hands-on sessions and are instructed by faculty, technicians, postdoctoral students, graduate students and high school teachers. Once the setup is installed in the schools, students are introduced to various data analysis tasks, for example the study of cosmic ray rate dependence on barometric pressure.

Figure 2: Left: Building a scintillator ground detector. Right: Brainstorming session.

2.2 Undergraduate Offerings

The undergraduate activities combine regular courses and research projects:

- An introductory course on scientific method, technology and modern cyberinfrastructure uses the atmospheric phenomena to motivate students in research activities. The objective is to introduce the different components of the project and let students propose their own topics of research and carry out a complete experiment.
- Various eight-session four-week inquiry-based courses through the WISE mentoring program are offered. The objective in this case is to provide with series of basic exercises for data analysis and comparison using the new technology.
- Engineering students have shown interest for the radar-like detector research and conducted their senior design project (one year duration) under the supervision of our engineering team. Last year a group worked on calibration of the instrumentation for signal acquisition, and currently another group is working on data analysis of radar data.

2.3 Research Projects

Some high school students have developed their Intel projects[2] under the supervision of MARIACHI researchers. MARIACHI has also offered the opportunity for teachers to participate in the ongoing research

[1] For a more detailed explanation of the MARIACHI research experiment please refer to (Takai, 2008).

[2] The Intel Science Talent Search is a US pre-college science competition.

experiments with many possibilities for personal as well as professional growth. As mentioned in the previous section, some undergraduate students have carried out their senior design projects in radar topics as well as some master students who are preparing their dissertations in data acquisition or cosmic ray detection, localization and classification.

3 MOBILE COMPUTING AND CYBERINFRASTRUCTURE

MARIACHI is a widely geographically distributed experiment and run by students and professionals of different backgrounds. The body of data collected by the experiment requires the use of modern day computer and network technology. The participants need to be trained in both the use of hardware and software to fully take advantage of this technology. The challenge of a widely distributed system is to provide mechanisms to guarantee data integrity and secure transfer. This is especially true when a diverse group is involved. The collaboration also needs secure collaborative tools such as the wiki and secure email.

In the context of the Mariachi project, cyberinfrastructure has several facets. Learning how to handle these tools is an essential step to perform experimental work in any area of science. Training and educating participants to use these tools is one of the main objectives of MARIACHI. This process takes place while the experiment explores its science.

Due to the physical separation of the experiment resources and participants, in the past the offered courses, workshops and projects needed a well defined set of activities that could not be properly combined and developed to full extent. The integration and exploitation of mobile technologies as well as modern cyberinsfrastructure tools has facilitated enhanced teaching and learning and efficient communication.

3.1 Use of TabletPCs

At the MARIACHI home, the exploitation of portable computing technology in the class provides with many opportunities for students to move from activity to activity writing notes easily, storing data, sharing results, asking questions, or presenting results (see Figure 3). Mobile computing in the form of TabletPCs has allowed for integration of the theoretical and practical components of the deliveries in only one classroom. All the needed resources are available to perform theoretical explanations, programming experiments, or research activities.

Figure 3: Use of a TabletPC during the summer workshop.

The use of TabletPCs has also enhanced the teaching and collaborative learning by providing multimedia support for friendly explanations and presentations. By connecting the TabletPC to a projector, we have a fully interactive presentation system that allows for delivery of highly visual and dynamic lectures with multimedia presentations and demos. Besides, all the notes, students' exercises, and live elements of the discussion sessions are saved, which facilitates keeping more accurate records of students' progress. It also allows a more individualized attention to the students. At the conclusion of the offered activities the participants are able to use the TabletPCs in a mobile situation to collect, share and compare experimental data from both the scintillator sites and the radar set-ups.

The communication between the instructor and the students and among students as they move from setup to setup has also been improved. Students and instructors are able to communicate even if they are carrying out different activities in different locations.

Finally, the TabletPCs are particularly good in MARIACHI for field work where connectivity is available and are used for field data collection and recording. In training sessions mobile technology is very useful for participants to perform different experiments at different stations in a laboratory setting while recording information.

3.2 Cyberinfrastructure in Action

MARIACHI has established a Linux-based server for data repository and dynamic web content services. One of the first projects undertaken was the creation of a website based on two growing and popular concepts: wiki and blog (Takai, 2008). The website is publicly accessible, but contributing and editing is restricted to registered MARIACHI users. The website has been enthusiastically received and many people have made substantial contributions. In particular

many of the participants have created their own personal user profiles which constitute an evidence of the diversity of the group. We are increasing the level and frequency of participation by assigning editors to specific areas of the wiki.

MARIACHI requires radar and ground detector sites with cyberinfrastructure for data collection and analysis. We demonstrated the ability to produce complete ground detector kits, build and install detectors in high schools, install antennas, and upload data to the MARIACHI server. The detector assembly workshops continues until the installation at currently affiliated high schools is completed. After the mechanical installation of each system, detectors are commissioned and calibrated in situ. Data uploading from behind high school firewalls has also been accomplished. This step is significant for the progress of MARIACHI as high school firewalls are extremely secure and protective. Interactions with information technology personnel from several schools were very important in this task. The data collection is now being implemented and the status of each site is displayed on our website (see Figure 4).

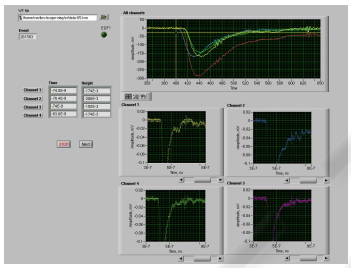

Figure 4: Oscillogram of signals and data collected from four detectors in a classroom.

Though the data rate is not very large, the nature of the experiments and searches to be performed require participants to become familiar in handling statistical data analysis. While spreadsheets such as Excel provide preliminary analysis, we are introducing modern statistical data analysis packages, such as R.

Finally, videoconferencing has proved to be a useful cyber tool to establish communication between MARIACHI sites. Its educational potential was demonstrated when Ward Melville High School students joined in a CERN (European Center for Nuclear Research) Masterclass program (Pregernig, 2008) using internet videoconferencing to discuss particle physics with students from Poland, Slovakia and Greece. We have installed and evaluated commercial software used by educators. Tests were conducted with local high school teachers and internationally with the University of Rio de Janeiro and CERN with positive results for audio, video and whiteboard.

4 CONCLUSIONS

MARIACHI's goal of bringing science and engineering research to classroom is achieved while students are exposed to cutting edge technology. For the participants, this infrastructure brings added flexibility, excitement, and innovation in their process of learning and support programs that are necessary for running the educational and research activities, and facilitates the communication between them (e.g., e-mail, instantaneous messaging, wiki).

The structure of the program has attracted additional sites not only nationally but internationally located. These new participants have already attended some of the workshops and courses and are implementing similar activities with the collaboration of our faculty, researchers and teachers.

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