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The QuarkNet/Grid Collaborative Learning e-Lab

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Abstract

This paper describes a case study that uses grid computing techniques to support the collaborative learning of high school students investigating cosmic rays. Students gather and upload science data to an e-Lab website. They explore those data using techniques from the GriPhyN collaboration. These techniques include virtual data transformations, workflows, metadata cataloging and indexing, data product provenance and persistence, as well as job planners for execution locally and on the grid. Students use web browsers and a custom interface that extends the GriPhyN Chiron portal to perform all of these tasks. They share results in the form of online posters and ask each other questions in this asynchronous environment. Students can discover and extend the research of other students, modeling the processes of modern large-scale scientific collaborations. Also, the e-Lab provides tools for teachers to guide student work throughout an investigation.
http://quarknet.uchicago.edu/elab/cosmic

Keywords: Collaborative learning; Collaborative computing; Distance learning; Education; Human factors; Hypertext/hypermedia; Information systems education; Distributed systems; Online computation; Physics; Web-based interaction

1. Introduction

Cosmic rays have been the subject of scientific research since 1912, when Victor Hess confirmed their existence from a balloon several kilometers above Earth. The upper atmosphere is awash with these particles, which are created in many astronomical objects. Most have low energies but still penetrate to the Earth's surface. More fascinating are cosmic rays with energies six times higher than current theory allows. High school students have an opportunity to contribute to this research.

QuarkNet [1] is deploying a network of classroom cosmic ray detectors in high schools across North America [2]. The detectors capture the time and location of the arrival of cosmic rays and save the data to a local computer (Fig. 1). They use GPS timing to ensure precise timestamps [3]. These detectors are sensitive enough to capture cosmic rays that fill in the energy spectrum from low to high and possibly even to see one of the rare high-energy events.

In addition to conducting individual studies for muon flux or lifetime, students are able to set up detectors to function as an array that covers an area including several schools. When the local data are uploaded to a central server, students in the collaboration can investigate data from one school or combine data from multiple sites. Students without detectors can also be active members of the collaboration by accessing and analyzing data.

The science lends itself to project-based learning, a system for organizing portions of the curriculum around ill-structured problems that help students acquire knowledge while building problem-solving skills. The science calls for collaboration, requiring students to function in an experimental environment similar to high-energy physics collaborations, in which the web plays a vital part in supporting research. They must participate in a network of users that needs access to computer

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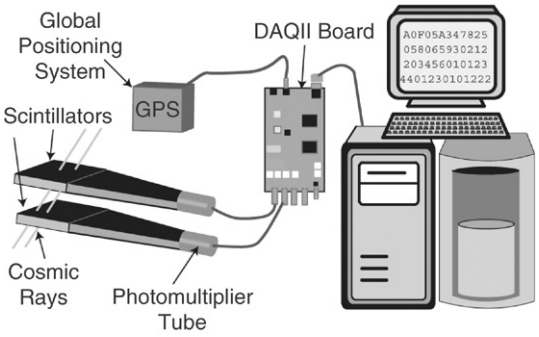

Fig. 1. The school-based detector.

cycles, storage capacity, shared data and data products, community-defined analysis tools, and communication tools to share and discuss results. The QuarkNet/Grid Collaborative Learning e-Lab (cosmic ray e-Lab) provides this online, cross-platform and ubiquitous environment.

The organization of this paper is as follows. Section 2 introduces the case study exploring the potential of supporting online student collaborative learning environments, e-Labs, which use virtual data grid tools and techniques. Section 3 describes a prototype e-Lab based on the study of cosmic rays and the website support for students and teachers. Section 4 describes the implementation, including the system architecture, the features of the virtual data system, and the Chiron portal central to the project and their specific uses in the e-Lab. Section 5 describes lessons learned. Finally, Section 6 summarizes the main contributions of the paper and discusses future work.

2. Case study

This case study assumes that some research experiments using grids will have data interesting to and appropriate for secondary school classroom investigations, and that partnerships of computer scientists, research scientists and educators can create online collaborative learning environments, **e-Labs**, for students. The foundation of an e-Lab is the grid infrastructure and virtual data tools and techniques; experiments provide data, analysis software and background material; on top of these resources, educators create user-friendly, single-purpose, application-specific web pages.

The case study is a partnership between QuarkNet and the GriPhyN [4] Project. QuarkNet is an education program for US ATLAS and USCMS, which are United States collaborations working on experiments for the Large Hadron Collider at the European Organization for Nuclear Research. Participants also work on as many as nine other high-energy experiments. A long-term program, QuarkNet brings high school teachers and their students into research groups nationwide. Students learn fundamental physics as they analyze live online data and participate in inquiry-oriented investigations.

The GriPhyN Project is developing grid technologies for scientific and engineering projects that must collect and analyze distributed, petabyte-scale datasets. GriPhyN research will enable the development of Petascale Virtual Data Grids (PVDGs) through its Virtual Data Toolkit [5].

The cosmic ray e-Lab research project explores the potential of using virtual data grid tools and techniques to support student data-analysis projects for US ATLAS and USCMS. A pilot cosmic ray study provides a chance for:

- Students to do authentic research — to access, process and publish data, report and share their results as online posters, and have online discussions with one another about their work.
- Student researchers to experience the environment of scientific collaborations.
- Student researchers to make contributions to a burgeoning scientific field.
- Educational researchers to evaluate the effectiveness of such an endeavor.

3. Collaborative learning environment

This case study envisions a collaborative learning environment where student research teams conduct investigations of real-world problems or issues through online projects that are collaborative, student-driven and technology-dependent. When skillfully applied, technology can enhance learning in new and powerful ways, such as allowing students to reach beyond classroom walls to collaborate and publish original work to a worldwide audience. When skillfully designed, projects can require collaboration among student groups and between students and experts. With appropriate management tools, students can design and carry out an investigation even though they are novice researchers, and teachers can facilitate student learning, track their progress, and assess their work.

The project shares a vision for technology-enhanced learning with such projects as EleGI [6] and GRIDCOLE [7]. Because the students will become “apprentice scientists” who use the grid as their professional partners do, the project starts with the emerging grid infrastructure being developed by GriPhyN and iVDgL [8]. A learning environment sits on top of an existing grid architecture used by scientists. The project does not attempt to build new grid-based services for the learning environment such as the Learning Flow grid services in the EleGI project.

From a learning perspective, the work is based on 12 years of experience with the LInC [9] Program, which has developed *demonstrators* that integrate best uses of non-grid technology with inquiry-based teaching and learning. The research base comes from the US Department of Education’s North Central Regional Educational Laboratory [10].

3.1. Student collaboration

In the cosmic ray e-Lab, students experience the environment of scientific collaborations in a series of investigations into high-energy cosmic rays. The collaboration is a student-led, teacher-guided project. Schools with cosmic ray detectors