Guest Editorial
Grid Education and Grid-Based Technologies Applied to Education: Ongoing Activities

GRID computing is often referred to as the next revolution after the Internet and the World Wide Web and evolved from high-performance and distributed computing during the 1990s. Although grid technologies were primarily intended to support computationally intensive scientific research because of the ever-growing need for computing resources, these technologies are increasingly being adopted in other domains, such as business, industry, or education, which is the scope of this special issue: Grid-Based Technologies Applied to Education.

Grid technologies enable the sharing, exchange, discovery, and aggregation of resources (processors, storage, scientific devices, information, knowledge, etc.) across geographically distributed sites. To achieve these functionalities, grid middleware usually provides the following components:

- security—user authentication and authorization in the grid infrastructure and support for data integrity and privacy;
- data management—discovery, transfer, and access of data in the grid;
- resource and job management—resource allocation and submission, monitoring, and control of jobs;
- information system—monitoring and discovery of hardware and software resources of the grid.

Grid computing builds on knowledge of Web services technologies, distributed computing, network security, and network architecture and programming. The Open Grid Forum (OGF, http://www.ogf.org), a community of users, developers, and vendors, leads the global standardization effort for grid computing, following open standards for grid software interoperability. Within this Forum, an ongoing initiative (started in 2006) is attempting to consolidate a Grid Education and Training Community Group (ET-CG) with the goal of sharing and developing best practice in grid-related education and training (including recommended curricula and teaching material).

Grid education and the use of grid technology in the teaching process is crucial to bridge the "grid digital gap." In this context arises the project Grid Technology To Enable Regional Development (CYTED-Grid, http://www.cytedgrid.org), funded for the period 2006–2009 by CYTED, the Latin American Program of Science and Technology for Development. The goal of this project is to contribute to the technological development of the Latin American region by promoting grid research and development activities and educational actions to provide university instructors with access to grid infrastructures and with a scientific and engineering skill for teaching and working within the rapidly expanding grid computing field.

The goal of this special issue is twofold. On the one hand, the rapid growth of grid technologies involves educational needs and challenges to promote their successful adoption and development. In this sense, the introduction of grid topics in the curriculum of disciplines such as Computer Science, Computer Engineering, or related fields, is a key factor. The first two papers in this special issue (both with NSF support) address this aspect: grid education, including practical experiences in grid curriculum design. On the other hand, grid technology has great potential for application in education, offering a framework that opens new ways of teaching and learning that have not been previously possible: grid-based remote laboratories, distance education using grids, grid portals to support courses in scientific and engineering disciplines, collaborative educational environments based on grid technologies, etc. The practical and successful application of grid technology to support courses in areas different from grid computing is the focus of the other two papers in the special issue. These kinds of experiences are still scarce, but they are expected to have a significant increase in the near future with the consolidation and adoption of grid technologies.

Related information sources within the scope of the special issue are the papers presented at the International Workshop on Grid Education (Grid.Edu 2004) and the International Workshop on Collaborative Learning Applications of Grid Technology (CLAG 2004), both held in conjunction with a leading grid conference: the IEEE International Symposium on Cluster Computing and the Grid (CCGrid). In 2005, both CCGrid workshops merged into one: the International Workshop on Collaborative and Learning Applications of Grid Technology and Grid Education. More specific is the scope of the European Union-funded project ELeGI (European Learning Grid Infrastructure, http://www.elegi.org) and the associated ELeGI conferences. The goal of this project is to define, implement, and validate an advanced service-oriented grid-based software architecture for learning.

The special issue is organized as follows. The first paper, "Teaching Grid Computing: Topics, Exercises, and Experiences," by Jens Mache and Amy Apon, describes grid educational material and infrastructure suitable for classroom use at two different U.S. universities (Lewis & Clark College, Portland, OR, and the University of Arkansas, Fayetteville) for undergraduate computer science students. The focus is on topics about grid security and on tools and languages for developing grid applications. The second paper, "GridFoRCE: A Comprehensive Resource Kit for Teaching Grid Computing," by Bina Ramamurthy, presents a suite of pedagogical resources to enable an instructor to embed grid computing topics (architecture, protocols, services, and applications) in an undergraduate distributed systems course curriculum. The suite includes course planning, lecture notes, laboratory exercises, a grid laboratory environment (hardware, software, and administration details) adapted to classroom material, and assessment instruments to follow the progress and

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outcome of the course implementation. The resource website provided by the author is a good starting point for those instructors wishing to introduce grid computing concepts into their courses. Although the courses proposed in both papers are based extensively on specific programming tools and environments (such as the grid middleware Globus toolkit, http://www.globus.org), the methodological and pedagogical lessons learned from these experiences are technology independent.

The third paper, "Grid-Based Virtual Laboratory Experiments for a Graduate Course on Sensor Networks," by Ioannis T. Christou *et al.* presents a remote laboratory for the execution of experiments (sensor network simulations) on a Globus-based grid environment. This paper addresses both pedagogical and technical issues. The sensor network laboratory is in the context of a distance-learning program, a Master's in Information Networking, between Carnegie Mellon University, Pittsburgh, PA, and Athens Information Technology, Greece. The grid-enhanced laboratory allows users to meet the computational requirements for running a large number of simulations using nondedicated resources and is designed to support team collaboration between students from geographically dispersed campuses for running the experiments (e.g., by means of collaborative configuration of the simulation parameters). Finally, the fourth paper, "A Grid-Powered Framework to Support Courses on Distributed Programming," by Paolo Maggi and Riccardo Sisto, describes a grid-based system accessible through a Web portal for the automated management and grading of programming assignments. Practical experiences are discussed in the context of a graduate course on distributed programming for students enrolled in an M.S. program in computer engineering at the Turin Polytechnic, Italy. The use of a computational grid is mainly justified by the computationally intensive correction tests demanded by the grading system (e.g., portability, field, and robustness tests), some of them requiring a distributed and heterogeneous environment. The grid-based framework is also designed to enable instructors not experienced in grid computing to easily set up a similar Web portal to support assignment submission and grading for their classes so that they only have to provide their own assignments and tests without getting into deep technical details.

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