Guest Editorial: The Many Facets of Remote Laboratories in Online Engineering Education

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1 Introduction

This paper is an introduction to the Special Issue on the Many Facets of Remote Laboratories in Online Engineering Education, published in the *IEEE Transactions on Learning Technologies*. Given the important amount of research in the field of remote laboratories, the problem was to come up with a set of quality papers to publish in a journal that would become a milestone for our research community. It is self-evident that a special issue in a journal such as the *IEEE Transactions on Learning Technology* can only provide insight on ongoing unpublished original work that was completed in time for the special issue. While it can, therefore, only describe ongoing research results in a specific time window, we attempt to present a set of complementary papers that can provide insights into several different aspects of this research field. In this introduction, we first address current trends in online engineering in order to explain the exponential growth of the need for remote engineering. The second part explains that it could only be addressed by enabling remote technologies to enter the learning experience delivered to the students. Finally, we conclude with a brief guide of the papers included in this publication.

2 Current Trends in Online Engineering

Remote engineering, also better known as online engineering, is one of the future directions for advanced tele-working/e-working environments not only in engineering and science (economics and informatics), but also in all other fields affecting society. In the last few years, we have witnessed considerable advances regarding the design and development of remote and virtual laboratories. These advancements have been possible because of the growing technical capacity of the Internet and new models of e-learning, distance learning, and e-work. The forerunners in this area are engineering disciplines and the natural sciences.

Remote engineering and virtual instrumentation are very relevant future trends in engineering and science because of:

- the growing complexity of engineering tasks,
- the increasingly specialized and expensive equipment, software tools, and simulators required,
- the necessary use of expensive equipment and software tools/simulators in projects with short time frames,
- the application of high tech equipment required in SMEs,
- the need of highly qualified staff to control new equipment, and
- the demands of globalization and division of labor.

Active learning, or working by means of remote laboratories, is especially valuable for distance education and e-working. Users in the workplace can access remote laboratories without having to travel. This flexibility is important for teleworking, education, and lifelong learning.

Remote laboratories are increasingly being used in industry, in part because:

- expensive and complex instruments can be used from different locations within the same company or can be shared by different companies,
- complex experimental systems, including specific media additions for cooling an inert gas, can be maintained by special equipment and staff at a specific location and can be directly controlled from the scientist's or engineer's office,
- team members working at different locations can effectively cooperate and take advantage of the same test-run results without any extra traveling, and
- long-term trials (reliability, failure performance) can be conveniently supervised from home, e.g., on weekends.

We have discussed the need for our society to develop approaches and tools for online engineering. This cannot be done, however, without educating students about online engineering. One possible option is to provide learning experiences that employ online engineering learning methods, and especially remote laboratories.

3 Remote Engineering in Online Engineering Learning

3.1 Online Engineering for the Society

Using remote laboratories has the potential of significantly reducing obstacles related to cost, time-inefficient use of facilities, inadequate technical support, and limited access to laboratories. This kind of development leads to the seamless integration of work and learning (embedded learning).

This also could benefit people with special needs and people working from home, as they would not need to

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travel to their company facilities to work. Even employees working at their company's facilities can use remote specialized equipment at another affiliate or company without traveling. This may provide new opportunities and benefit SMEs that would not otherwise be able to use such equipment. There is a worldwide lack of specialists in this field and the number of needed specialists is expected to dramatically increase in the coming years.

3.2 "The Lab Will Come to You"

These reasons have lead universities to envision new geographical and temporal patterns to deliver higher education. The "anytime, anywhere" paradigm in the field of distance learning (pervasive learning), developed during the 1990's, has contributed to bringing the university right to the student's door through the Internet. In 2005, Jesus del Alamo, principal investigator for the project of bringing MIT Labs to students in Africa and professor of the Department of Electrical Engineering and Computer Science, promised:

> "If you can't come to the lab, the lab will come to you" [1].

Although traditional laboratories have always played an important role in education, online laboratories for distance education will increasingly gain importance. There are many kinds of online laboratories, however, the most common online laboratories are virtual laboratories (model-based Web simulations that complement hands-on exercises), remote laboratories (real remote control of devices for distance learning hands-on sessions), and hybrid laboratories (a mixed approach: one part simulation and another part real remote control).

This special issue focuses on remote laboratories, as they tend to be more commonly used in distance learning modalities that attempt to provide local learning experiences.

However, today's experiments have become increasingly more complex, requiring ever more specialized and expensive equipment. Presently, only some large research centers and perhaps some universities can afford such costly equipment, and even more fortunate institutions can only partially acquire what they need. Remote laboratories can provide a viable solution that permits greater access to limited resources and adapt to ongoing changes in learner online interactions and learning facilities. Several significant and original research projects have emerged around the world, and each of these projects contributes to creating the many facets of remote laboratories ([1], [2], [3], [4], [5], [6], [7], [8]).

3.3 Remote Laboratories and the Learning Experience

Meanwhile, modern learning theories, including constructivism, have emerged and been more greatly employed in higher education teaching practices. This trend has significantly modified the traditional learning process model. Students today are increasingly expected to construct and deconstruct their knowledge as individuals by employing knowledge, abilities, and competencies acquired through their learning experiences and their interactions with instructional materials, media, peers, and instructors, all as a part of a well-planned and implemented curriculum. In the field of engineering education, this suggests a more significant contribution of hands-on approaches that improve the quality of learning. Hands-on approaches support several pedagogical objectives: They compare theory and practice, they help students learn how to employ specific tools and devices, and they provide real-world situations that require interaction with peers in circumstances that require problem solving skills developed through close collaboration, which are characterized by initiative, creativity, etc. This also emphasizes the need to use experiments within online learning activities, in part because these online activities permit students to interact in multicultural settings that transcend national boundaries, reflecting present and future business and academic and scientific interaction.

3.4 Remote Laboratories in the *IEEE Transactions on Learning Technologies*

During these last years, many remote laboratory platforms have been developed and used in distance learning situations. The primary focus of research has been to tackle issues related to software development for remote laboratories. Because of the importance of software development issues, many other significant areas of study, including distributed architectures, reusability, performance, platforms, learning management system, eCollaboration, authoring tools, methodology, and evaluation, among others, were somewhat secondary.

Remote laboratories have the potential to significantly reduce obstacles related to cost, time-inefficient use of facilities, and inadequate technical support and limited access. This kind of development leads to the seamless integration of work and learning through practical knowledge that reinforces theoretical knowledge by actually resolving physical or mechanical problems (embedded learning).

4 Special Issue Papers

It is self-evident that a special issue in a journal such as the *IEEE Transactions on Learning Technology* can only provide insight on ongoing unpublished original work that was completed in time for the special issue. While it can, therefore, only describe ongoing research results in a specific time window, we attempt to present a set of complementary papers that can provide insights into several different aspects of this research field. The selection of nine papers for the special issue is by no means an exhaustive view of all the tremendous work that currently involves remote laboratories. Other approaches and points of view can be found in references [9], [10] or discussed online [11].

The papers in this special issue first stress the stakes and issues in remote laboratories [12], especially focusing on ongoing trends in terms of applications and identified scientific deadlocks that need to be addressed [13]. It moves afterward to papers that provide valuable feedback concerning some specific cases of significant work from around the world (Australia, Europe, etc.) in terms of developing remote laboratories [3], [14], [15], [16] and collaborative remote laboratories [17], [18]. Finally, a paper offers an

interesting point of view on lessons learned from some achieved projects of remote laboratories [19].

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Guest Editors

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