Part III
Cyber-Physical Laboratories: Best Practices and Case Studies

Section Introduction

This section highlights a number of remote laboratory case studies covering a range of application areas that can be considered as representative best practices. There is a total of six chapters highlighting remote laboratories for life science experiments, automation engineering, hardware-in-the-loop systems, integration of augmented reality and haptic devices, heat transfer experiments, and additive manufacturing. The contributions provide an insight from a different perspective, and each discussion leads the reader to understand the rationale behind the approaches taken and obtain further information of interest.

Almost all reported remote laboratory developments are related to engineering, technology, and physics topics; our first chapter for this section is introducing a remote laboratory development in biological science. This chapter is titled as "Life-Science Experiments Online: Technological Frameworks and Educational Use Cases" by Zahid Hossain and Ingmar Riedel-Kruse. The chapter describes and compares four biology cloud laboratories demonstrating different user interaction modes, underlying hardware and software architecture, biological content, and scalability issue. In addition to the educational use, the chapter describes research applications. The authors illustrate the general design rules for biology cloud experimentation laboratory along with open questions regarding future technology and opportunities for scalability and wide deployment.

The second chapter titled "A CPS Integration Platform as a Framework for Generic Remote Labs in Automation Engineering" by Reinhard Langmann describes the development of a generic or customizable remote laboratory utilizing a web-oriented automation system (WOAS). This uses the new paradigms from cyber-physical systems and service-based automation. The platform allows one to develop a remote laboratory with given requirements using web-based tools. The author describes the use of the WOAS portal as a framework for creating user-specific remote laboratory for automation technology training and demonstrates its effectiveness through three applications.

The third chapter of this section presents the development and utilization of an additive manufacturing (AM) laboratory environment. The chapter is titled as “The Development and Implementation of Instruction and Remote-Access Components of Additive Manufacturing” by Ismail Fidan and his co-authors. The chapter starts with highlighting the historical funding support the team has received for developing this remote laboratory. This is followed by a discussion on AM technologies and how this system has been accessed over the network for remote communication. The authors then illustrate the details of their developed remote laboratory facility as well as the instruction materials used for course delivery. Finally the chapter concludes with the presentation of student feedback while utilizing the facility for educational delivery.

The fourth chapter “Design and Implementation of a Remote Laboratory for Heat Transfer Experiments” by Ridha Ennetta and his co-authors describes the design and the implementation of a remote laboratory for heat transfer learning purposes. It summarizes the work carried out to adapt and redesign a heat exchanger bench to be remotely accessed and controlled. This laboratory introduced many fundamental aspects of heat transfer, both theoretically and practically. An evaluation procedure was also carried out for this development, while focusing on technical and pedagogical aspects. The evaluation results demonstrated that the expected learning outcomes of this remote laboratory seem to be very interesting compared to conventional laboratories.

The fifth chapter “Collaborative Virtual Laboratory Environments with Hardware in the Loop” by Zhou Zhang and his co-authors highlights a virtual laboratory system with experimental hardware in the loop. The chapter discusses the concept, history, and current status of virtual laboratories as well as techniques used to create those. This is followed by presenting its shortcomings and promising approaches for overcoming those. The authors closed the chapter with a pilot implementation of two laboratory experiments along with evaluation studies of participating students. The results indicated that the developed virtual laboratory environments were well received by the students.

The last chapter of this section which is titled as “Mobile Cyber-Physical Labs: On the Integration of Mobile Devices with Laboratory Test-Beds to Teach Dynamic Systems and Control Concepts” by Jared Frank and his co-authors proposes the use of mobile cyber-physical laboratories in which the hardware and software of mobile devices are leveraged in the measurement, control, monitoring, and interaction with physical test-beds in the laboratory. Two separate approaches for developing cost-effective and portable educational test-beds are proposed. These utilize the sensing, storage, computation, and communication capabilities of mobile devices to facilitate inquiry-based educational experiences.