Distributed Learning Environment Support for Remotely-accessed Embedded Systems

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Abstract:
Distance-learning engineering courses supporting remote laboratory experimentation, afford a number of critical benefits including flexible access to resources. However, creating an effective and integrated learning environment which allows the access, control and monitoring of embedded devices and instrumentation over the Internet is challenging. Recent advances in web technologies and applications have enabled increased levels of functionality and accessibility for remote laboratories. This paper presents a generic distributed learning environment which addresses the flexible integration and control of a currently available remotely-accessed embedded system laboratory at the University of Ulster.

1 Introduction

Experience has shown that effective teaching in engineering disciplines requires an interdependent approach combining theoretical material underpinned by practical laboratory experiments. Remote experimentation offered as part of a web-based learning approach affords a number of critical benefits and for engineering distance education courses as it is the only realistic method of performing many experiments. This approach allows remotely located users to complete laboratory assignments unconstrained by time or geographical considerations while in the process developing skills in the use of real systems and instrumentation. Recent advances in web applications, communication tools and domain related technologies have enabled complex client server multi-faceted integrated learning environments to support the access and control of remote laboratories. Such environments can potentially offer users a high level of access to extended functionality on remote laboratories. However, learning environments supporting remote experimentation for embedded systems need to efficiently integrate a number of components to offer the diverse level of user functionality required.

This paper describes recent work on learning environment support for the DIESEL project [1] (Distance Internet-Based Embedded System Experimental Laboratory), a three year distance learning project funded by the EPSRC under the Masters Training Program and located at the Intelligent Systems Engineering Laboratory on the Magee campus of the University of Ulster, N. Ireland. The objective of the DIESEL project is the provision of remotely accessed laboratories for an Embedded Systems Design module [2] on the MSc. Computing and Intelligent Systems course at the University. These remote experimentation facilities complement and extend the existing MSc course by enabling students to conduct practical
experiments in Embedded Systems remotely via the Internet. To date, a remote-access hardware architecture and distributed learning environment has been developed and implemented. The learning environment facilitates the distributed interaction between the user and the remote-access hardware architecture of the remote laboratory. Details of the distributed learning environment and its support for the laboratory are presented in this paper. Section 2 of this paper summarises current research and previous work by the authors. Section 3 discusses the distributed learning environment and its ability to support the interaction, control and monitoring of remote-access architectures. Section 4 provides a summary of the paper.

2 Remote Experimentation

Several key deficiencies have been identified in current web-based remote experimentation laboratories including the lack of flexibility in instrumentation set-up and support for distributed learning environments. Existing laboratories tend to be crude in nature and fail to fully utilise and support existing design, test and debug software and equipment [2-3]. In addition, current learning environments do not support the required levels of functionality through the provision of access to modern commercial design tools or the ability to manipulate connections between circuits and instrumentation. Providing increased levels of functionality for the learner is dependent not only on the method of integrating hardware components for remote-access, but more importantly, on the environment in which users perform the access, control and manipulation of the physical hardware equipment. The effort and re-development costs needed to re-design and adapt existing hardware and software tools to support online remote access are difficult and require multi-disciplinary expertise.

Previous work by the authors has addressed some of these issues through the design and implementation of an integrated hardware architecture, which supports control and monitoring of embedded systems experiments and instrumentation remotely over the Internet [4]. The DIESEL architecture supports the remote-access and control of a range of embedded systems experiments currently available on Master Degree courses at the University of Ulster.

![Figure 1. DIESEL Facilities](image-url)
The hardware architecture integrates the instrumentation and experimental components of the system and is functionally comprised of three distinct but interconnected sections; learning support resources, remote experimentation facilities and collaborative working and communication tools. Figure 1 illustrates the component features of the DIESEL architecture [5]. The learning support resources include extensive lecture and laboratory notes complete with audio/visual content providing theoretical background material and guidance for experiments. The remote experimentation facilities include the remote desktop feature which allows students to fully access all the resources of the distant workstations. A series of Macromedia Flash based executables provide a user interface front end to the experiments which control the switching equipment on the remote workstations. This interface allows students to effectively wire up circuits and to connect test equipment for the taking of measurements or readings. Instrumentation control is provided by a series of Labview virtual instrument interfaces to closely resemble the physical characteristics of typical test equipment, including oscilloscopes, digital multi-meters and function generators. The Labview interfaces allow the student full control of the test equipment and instrumentation connected to the remote workstation.

To provide feedback to the students during experiments, a series of Labview interfaces have been designed to connect to data acquisition cards which take readings from a range of peripheral devices e.g. Stepper motors. This is augmented by the use of Web cams to provide visual feedback. The collaborative working, support and communication tools were built using the Macromedia Flash communication server. This feature allows advanced interaction between students or between students and course support staff via audio/video and text. Current work by the authors focuses on the support of an integrated learning environments for the seamless access, control and monitoring of remote-access laboratories and in particular, for the current DIESEL laboratory [1] available at the University of Ulster.

3 Distributed Learning Environment

The DIESEL laboratory hardware architecture consists of several embedded systems experiment boards, instruments and signal routers, all of which are user-configurable [4]. Fig. 2 illustrates the DIESEL architecture highlighting the routing and switching interconnect between the embedded experiments and instrumentation. Embedded system boards can be programmed by the user to perform any number of tasks. Instruments are configurable and support the input or capture of signals from embedded systems experiments under examination. Signal routers are programmed by the user to provide feedback through connectivity between instruments and experiments.

The distributed learning environment supports the user-control and feedback of responses from the DIESEL remotely-accessed embedded system laboratory. The environment provides several levels of abstraction from the configuration of the hardware, providing a learning environment similar to that experienced in the labs. The additional signal routing and connectivity features, necessary to support Internet remote-access, are latent to the user. To address the abstraction from the lab hardware architecture, the environment is distributed between DIESEL client and server applications with a four-layered communication model. Fig. 3 illustrates the distributed environment and its connectivity with hardware architecture through four communication layers; presentation, data, business and physical. This approach to learning environment design provides efficient integration and management of the current functionality demanded by remotely accessed labs, and in particular the DIESEL features highlighted in Fig. 1.
Fig. 2 DIESEL laboratory hardware architecture
In addition, the four-layer communication model allows for future functionality of the laboratory to be supported without modifying the underlying hardware architecture. In such cases, only the upper layer (DIESEL client) of the model requires modification providing a standard interface between client and server applications.

Fig. 3 highlights the DIESEL client encompassing the presentation layer, which provides the user-interface to the laboratory, allowing downloading and configuration of embedded systems and instruments remotely. This is the only software component which needs to be installed on the user machine to provide remote-access, and also modified to accommodate future functionality. The remote viewer within the client displays all desktop software required to program and debug the embedded experiments. All control facilities, lecture material, tutorials and camera feedback are also encapsulated in the client. Fig. 4 illustrates the DIESEL client and the components of the presentation layer; namely the remote viewer client, circuit connector, lecture viewer, camera window and instrument panels.

The data layer of the model provides user and experiment information from a database. The information is used to inform lower layers of the model on the user selection of particular experiment boards during a laboratory session. The web services which are hosted on a database server in the remote laboratory, provide secure internet communication for passing control data between the client and the business layer of the DIESEL server. The DIESEL server which is hosted in the laboratory, encompasses both the business and physical layers. The business layer configures embedded circuits, signal routers, instruments and sends commands to the circuits for typical hardware reset. Any wire connections made by users in the displayed embedded systems circuit diagrams of the client, are automatically implemented in hardware through this layer of the model. In addition, the layer handles transmission of the embedded software’s desktop display to the remote viewer in the client.
In essence, the business layer responds to all user requests by executing the appropriate control programs for downloading embedded software, making connections and controlling debugging instruments in the hardware architecture. The lowest layer of the model, physical, encompasses all communication between the physical embedded systems and instrumentation equipment in the laboratory. This includes all physical switching and routing devices used to create the DIESEL hardware architecture.

The DIESEL learning environment uses the communication model to access and control the remotely located resources of the laboratory and is distributed through the allocation of the presentation, data and control services on three separately located machines in the lab. User machines accommodate the client component, in the remote lab the DIESEL workstation partly supports the hardware architecture and a third workstation in the lab accommodates the control services and database. The learning environments combined approach of layered communication and distributed services enables users to effectively control and experiment with real embedded systems and instruments over the Internet. In addition, the modular approach supports future extensions and upgrades to the DIESEL laboratory architecture without modifying the lower layers of the model, providing a standard software interface. In particular, the distributed learning environment can be used by other remote labs which support the software interface of the lower layers of the communication model.

4 Conclusion

This paper presented a learning environment for remote experimentation which addressed a number of deficiencies of current remote access laboratories. A distributed environment for remote experimentation was introduced which detailed the integration of several control and monitoring facilities with a remote-access laboratory architecture. The communication model
of the environment was presented and demonstrated the novel and effective strategy of remotely controlling advanced embedded system experiments and instruments over the Internet.

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