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1 Introduction

1.1 Remote Laboratories

Remote laboratories enable students to access physical laboratory apparatus through the internet, providing a supplement to their studies and existing hands-on experience. Students carry out experiments using real equipment, but with much greater flexibility since access can occur from anywhere and at any time. Their interaction with the remote equipment is assisted by the use of data acquisition instrumentation and cameras, providing direct feedback to students for better engagement. Traditional engineering laboratories require students to be physically present in order to work with equipment, which may limit student flexibility. Conversely, remote laboratories let students work in their own time and even repeat experiments for better learning outcomes.

Of course students cannot actually touch and feel the equipment in a remote laboratory, but they can still perform most other tasks relevant to their learning. Sometimes, separation from potentially hazardous equipment is preferable from a safety point of view. Due to the increased use of remote operation in industry, where machinery and entire plants are often controlled from a distant location, students may directly benefit from learning how to remotely control equipment. Furthermore, remote laboratories provide the opportunity to access a wider range of experiments as costly or highly specialised equipment may not be locally available. This presents the opportunity to share laboratory facilities between institutions.

Significant research and pilot studies have been undertaken in Australia and by several groups around the world into the educational effectiveness of using remote laboratories. These studies have consistently shown that, if used appropriately in a way that is cognizant of the intended educational outcomes of the laboratory experience, remote laboratories can provide significant benefits. Indeed, multiple research studies have demonstrated that whilst there are some learning outcomes that are achieved more effectively through hands-on experimentation (e.g. identification of assumptions, specific haptic skills), there are other learning outcomes that are achieved more effectively through remotely accessed laboratories (e.g. processing of data, understanding of concepts).

1.2 FPGA - The Rig Apparatus

Field Programmable Gate Array (FPGA) is a semiconductor device consisted of a number of programmable logic blocks, distributed memory, I/O pads and programmable interconnectors.

FPGA's and digital circuits are used heavily in industry for digital signal processing, multimedia controllers, imaging, telecommunications, consumer devices, custom logic and prototyping computer chips.

Current FPGAs are mostly SRAM based and usually slower with higher power consumption and the bitstream. However, it has shorter time to market, a reprogrammability and lower research & development costs. The FPGA design is converted from the Hardware Description Language (VHDL or Verilog) to a bitstream which is then used to program the device. Some FPGAs have on-chip storage for the bitstream where others have to be loaded from an external memory chip. The bitstream is loaded at the power on; once programming is finished, the design starts running on the FPGA.

The Remote Laboratories’ FPGA Rig allows students to upload and test bitstream files that were designed in Xilinx web pack by students.
The FPGA Rig is based on a Burch X5-300 FPGA based on the Xilinx Spartan2E architecture.

The rig is composed of:
- I/O header A is connected to the Burch B5 – LEDs board populated with 16 discrete surface-mount LEDs
- I/O headers B and C are connected to two Burch B5 – Dual Twin 7-segment displays
- I/O header D is connected to the Burch B5 – Peripheral Connectors Board, currently unused
- I/O headers E and F are connected to the Burch B5 – SRAM Board, providing 2 Mbytes SRAM accessible as a 128K x 16-bit array
- I/O header G is connected to the Burch B5 – Audio-Out Board, providing monophonic sound out, currently unused
- I/O header H is connected to the Burch B5 – Advanced Download Board, providing the PC programming interface as well as a parallel port to the FPGA interface for digital I/O. Parallel port data line D0-D7 are inputs to the FPGA

The LEDs and 7-segment displays are monitored by an iSight webcam, which is connected to the network, which provide visual feedback of the rig in action, with a small time delay.

Users should have a basic knowledge of electronics and interfacing. Also, users should be familiar with binary number systems (including arithmetic, multiplication and division).
2 Rig Session

The following section outlines the procedure for using the FPGA Rig, which is similar to other Remote Laboratory Rig types used in the past. The software that runs the Remote Laboratories and provides access to the rigs through a web browser is called Sahara.

For the purpose of using the rig, it is assumed that users have access to a workstation that meets the Remote Labs’ system requirements. Users should refer to Labshare’s Generic Rig Access Guide for this information.

After logging in with a username and password, the user will be directed to the “Rig Selection” page. Selecting the generic “FPGA” rig under Rig Types will randomly allocate the user to an available rig. However, if the user wishes to access a particular rig, then this can be selected in the Specific Rigs section. Once a rig is selected, a popup will appear, asking if the user wishes to join in the queue for the chosen rig. By clicking “Queue” button, the user now has an access to the selected FPGA rig.

![Rig Selection Screen](image)

If the rig indicates “In Use” status, the user will be put in waiting list to access the rig until current user and any other previously queued users are finished. The user’s position in the queue may be forfeited if the user navigates away from the queue page.
2.1 Using the Rig Page

If the rig is free, the user will immediately be taken to the rig page where the user can access the FPGA rig to load a designed program. Each user has a designated session timeframe to conduct a desired number of experiments. A countdown timer at the top left of the page indicates how much time the user has left on the rig. This may be automatically extended if no other users are waiting to use the rig. The rig session starts as soon as the user is directed to the “Rig Session” page. If the user does not utilize the rig session within the timeline that is given, the rig session may be forfeited.

From here, the user can perform an evaluation to verify that the rig is operating properly. When the user clicks on the “Program Demo” button, it will upload a demonstration bitstream to the FPGA rig, which in turn light up the display panel with 0s. Note that it may take a couple of seconds for the user’s remote connection to be established when loading a program on to the FPGA.

Next screenshot indicates the demo program has been loaded – “Operations List” on the left of the web page indicates system status messages and emergency announcements.
The input panel displayed below the video box contains two push buttons and six toggle switches that are mapped to the first 8 I/O lines of Header H of the FPGA rig. Each switch and button can be operated with the mouse.

Once finished with the program demo, the user can click on “Soft Reset”, which resets the FPGA to go back to the programmed state. Or “Hard Reset” button can be selected, which allows the user to reset the power cycle of the FPGA rig. This will clear any loaded bitstream files, reset configuration data and reset the switches back to the default (off) state.
When the user is ready, the user's bitstream file can be loaded to the FPGA rig from the user's system shown on the above screenshot.

If the user has finished using the rig completely, then the user can exit the rig session page by pressing the “Finish Session” button. A popup window will appear asking for a confirmation of exit.

Selecting “Yes” will close the current remote connection to the rig and bring the user back to the Rig Selection page. It is important that the user exits the current rig session properly before logging out of the Remote Laboratories web page to allow other users to access the rig.

Once successfully logged out, the user will be redirected to the main login page of Remote Labs.

2.2 Data Acquisition

It is assumed that the user is familiar with the use of web-based mailing system to send e-mail messages and file attachments. This method is easy to use and requires no additional software apart from a web browser. The user can e-mail oneself to transfer data files as needed. The users should be aware that e-mails can be delayed in transit and take time to be sent and received.
3  Rig Software

Users are recommended to use Xilinx web pack or ISE Version 9 or 10. However, ISE or web pack versions 11, 12 and 13 are not supported by the Spartan2E FPGA's, so it CANNOT be used for the Remote Labs FPGA's.
4 FAQ & Troubleshooting

Any questions regarding the nature of assessment tasks should initially be directed to the relevant academic. If the user encounters any difficulties using the rigs, the “Contact Support” button should be used to request assistance or report problems. The following popup window will appear, allowing the user to enter name and a valid email address. Then the most appropriate category should be selected from the drop down list, and the purpose of the help request should be briefly stated. A more detailed description of the problem, comment or request can be given in the feedback box.

Users are strongly encouraged to leave feedback and comments of their experience with the rigs to help improve the system, as well as any suggestions for additional features to be included in the future.

For any enquires or assistance, contact the Labshare helpdesk at:

helpdesk@labshare.edu.au