MELODI: A Mass e-Learning System for Design, Test, and Prototyping of Digital Hardware

Friedrich Bauer*, Felix Braun*, Daniel Hauer*, Axel Jantsch*, Markus D. Kobelrausch*,
Martin Mosbeck*, Nima TaheriNejad*, and Philipp-Sebastian Vogt*
Institute of Computer Technology, TU Wien, Vienna, Austria

For profound learning of digital hardware design, practical experience is of paramount importance. Hardware Description Languages (HDLs) have made the design process significantly easier and more accessible to masses. They enable fast design of circuits that can be tested in simulators or on real hardware. For the latter, Field Programmable Gate Arrays (FPGAs) play a crucial role in facilitating and speeding up the prototyping process.

When teaching digital hardware design, testing and prototyping in the academic field of HDL, it is important to help students develop the necessary coding skills, but this is not enough. Furthermore, the students must develop a good understanding of the the hardware (FPGA) itself and its reaction to the code. In a university course with hundreds of students, it is a challenge and very resource-intensive to provide all students with the necessary first-hand information. Each student, or a small group of a few, would need a complete tool-chain set up and access to FPGAs and peripheral hardware. In addition, the evaluation of students requires a considerable amount of resources and time.

Mass E-Learning of design, test, and prototyping DIgital hardware (MELODI) is based on our previous VHDL E-Learning System (VELS [1]) and provides an efficient and economical full-stack solution for the above mentioned students and universities. Especially for distance or e-learning facilities, which, due to the current pandemic, are no longer an option but rather the main solution around the world. Our system communicates with students via email. It automatically generates tasks (random variation of a template made by the teaching team) for the students. Students submit their task via email, which is then tested by the simulator on the server and a feedback is sent back to the students. Once the students solution is assessed as correct, it is automatically forwarded to the remote hardware. That is, a FPGA development kit enhanced with various (electrical and mechanical) hardware. MELODI uses partial reconfiguration to allow the shared and efficient use of a minimum hardware configuration by a maximum number of students simultaneously without mutual interruption. It automatically extracts the required hardware resources based on the HDL code, assigns it to the queue of one of the partial reconfiguration slots on the hardware and provides students with a website link. This web page provides visual feedback (through a camera) of the hardware as it executes the submitted code. Adiddionally, students then interact with their hardware using virtual buttons. Internally, MELODI provides a web interface for the teaching team to create tasks, monitor the operation of the system, and collect statistics on the operations, usage and students performance.

On the students' side, the requirements are minimized; all they need is an email account, any text editor, a browser and internet connection to go through all the steps of designing, testing and prototyping digital hardware. They can also adapt their learning pace to their own rhythm, as they can use the entire system anytime and anywhere in the world.

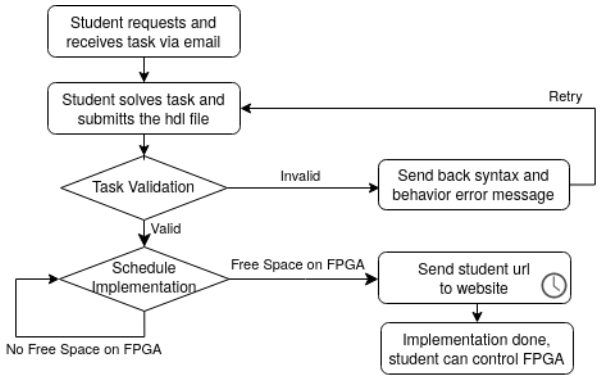

Fig. 1: Overview of workflow with MELODI

On the university side, the required resources are also significantly reduced. No more laboratory space or equipment are needed. A server with the corresponding licenses and at least one FPGA development kit are the only non-personnel cost. Especially, the partial reconfiguration used in MELODI improves the resource utilization and reduces the required waiting time for students to access each FPGA.

Compared to existing systems such as [2], the combination of automatic task validation and partial reconfiguration saves considerable amount of time and resources of the staff, who only have to maintain a single system (MELODI) as opposed to an entire laboratory. This enables remote mass e-learning without sacrificing practical experience.

References

[1] M. Mosbeck, D. Hauer and A. Jantsch, "VELS: VHDL E-Learning System for Automatic Generation and Evaluation of Per-Student Randomized Assignments, NORCAS 2018, doi: 10.1109/NORCHIP.2018.8573455..

[2] C. A. Mayoz, A. L. da Silva Beraldo, A. Villar-Martinez, L. Rodriguez-Gil, W. F. M. de Souza Seron and P. Orduña, "FPGA remote laboratory: experience of a shared laboratory between UPNA and UNIFESP," TAEE 2020, doi: 10.1109/TAEE46915.2020.9163773.

*Authors are listed alphabetically.