MELODI: An Online Platform for Mass Education of Digital Design - HDL to Remote FPGA

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, {firstname.lastname}@tuwien.ac.at

Learning and teaching digital hardware design involves significant efforts on both sides, teachers and students. Hardware Description Languages (HDLs) simplify the design process, where the created designs can be tested either in simulators or using real hardware. For the latter, Field Programmable Gate Arrays (FPGAs) play a crucial role in facilitating and speeding up the prototyping process. Mass E-Learning of design, test, and prototyping Digital hardware (MELODI) is developed for scalable teaching of HDL to a large number of students. The primary goals are to a) minimize the requirements for students and b) reduce the resources required at the university. MELODI provides a complete HDL workflow, including real remote hardware prototyping on FPGAs without the need for any tool at the students' side.

Excellent HDL coding skills are as essential as a good understanding of the hardware (FPGA) itself and how it responds to code. Teaching these two requires significant effort in terms of resources. Especially for a university course with hundreds of students, it is challenging to provide first-hand information, evaluate the submissions, provide individual feedback, and give individuals access to a complete tool-chain setup and FPGA hardware.

To overcome the challenges mentioned above, we developed an economical full-stack solution, MELODI, based on our previous VHDL E-Learning System (VELS [1]). Our system interacts with students via email and provides them with all necessary information from an initial task description to the remote FPGA access. Tasks are randomized variations based on templates (designed by the teaching team) and are automatically sent to the student in case of a request. Students submit their solutions via email, which are then tested and verified by a simulator on a server. Detailed feedback is sent back to the student in case of a wrong design behavior or syntax errors. Once the verification is successful, the design is automatically forwarded to the remote hardware. That is, an FPGA development kit connected to various (mechanical and electrical) hardware. MELODI uses partial reconfiguration to enable the sharing and efficient use of minimal hardware by a maximum number of students, using the hardware simultaneously without interrupting each other. During this process, the required hardware resources based on the HDL code are automatically extracted and assigned to the queue of one of the partial reconfiguration slots on the hardware. Students are then given the scheduled time of the respective resource allocation along with a website link. This website provides visual feedback (using a camera) of the hardware as it executes the submitted code. Additionally, the provided HTML user interface enables the control of the hardware using virtual buttons.

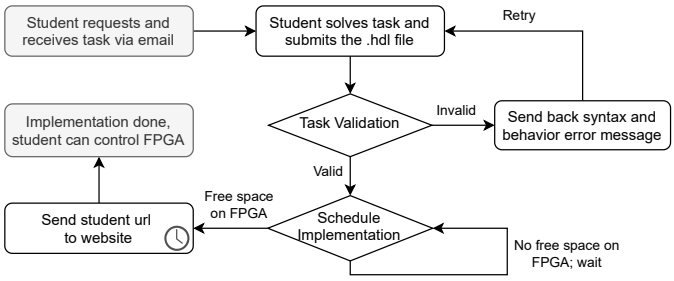

Fig. 1: Overview of workflow with MELODI

On the students' side, MELODI minimizes the requirements to an email account, any text editor, as well as a browser while still providing the whole design cycle from a task description to hardware prototyping. Students can individually adapt their learning pace, as they can interact with MELODI anytime and anywhere. This is an essential factor that has become even more important during the current CoViD pandemic.
On the university side, MELODI provides a full-featured web interface for creating and configuring new tasks, monitoring system operation, and tracking statistics on operation, usage, and student performance, while significantly reducing the required software, hardware, and human resources for large courses. At least one FPGA development kit, the connected hardware, and a server with the needed licenses are the only non-personnel costs. Maintaining a single system (MELODI) instead of multiple setups in a laboratory saves a considerable amount of work time and staff resources.

MELODI's strength comes with the combination of automatic submission validation and partial reconfiguration. Compared to other existing systems such as [2], our mass e-learning system maximizes the practical experience for students while minimizing the university resources.

*Authors are listed alphabetically.

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
[2] C. A. Mayoz, et al., "FPGA remote laboratory: experience of a shared laboratory between UPNA and UNIFESP," TAEE 2020