



safe for the physical system. This means, damage could be caused by invalid commands. The task of the protection unit is to check for command safety by filtering all commands. Only commands that will not cause any malfunction are executed. All others are discarded and optionally reported as an error condition to a learning management system (LMS). This concept can be used with all control units like Microcontroller, FPGA, PLC, etc. Using such a universal protection unit gives the students the largest degree of freedom for their design, because no precautions have to be taken into account. Therefore, no additional security framework (workbench) within the software and hardware control design is required to prevent malfunctions of the physical system [4].

The complete design flow is carried out at the students' side, giving them a more authentic look at a real world project design flow. The valid behavior of model protection unit is compared against the commands received from the control unit to determine any unsafe control commands of a faulty student's control algorithm. Commands that are valid for the current state of the physical system are passed. Commands that are not valid and could cause a failure or any other unwanted behavior are discarded and optionally reported. Besides pure web based training for students, controlled by the control units, the PSPU also offers the possibilities to be accessed by the teachers over the Internet for e.g. initialization of experiments or be accessed by local control. It is also possible to mix signal sources e.g. to get certain sensor signals from the model and supply others via a web interface.

This can be used in cases where a user input at the models is required to test the system behavior (e.g. a key press at an elevator). The details of the different modes and possibilities will be described in the paper [4, 5].

### III. EXPERIMENT CONTROL PANEL

On client side (student's PC) GOLDi offers a Web-based environment – the *experiment control panel* (ECP) – supporting the above mentioned features to generate and execute a design by using simulation models. The increasing capacity of wireless communication and the growing number of mobile devices (e.g. smartphones and tablets) on the one hand as well as modern Internet technologies like JavaScript, HTML5 and Web Sockets on the other hand provides new possibilities and challenges in the area of mobile learning. Therefore a realization as HTML5 application was chosen for the Web-interface.

By using the ECP, the student is able to:

- upload the synthesized/compiled designs to the corresponding Web-control units in the lab room,
- handle the experiment (e.g., start, stop, reset),
- use the interactive debugging features (break on sensor/actuator changes or special conditions),
- change environmental variables if necessary and
- watch the experiment by manipulating environmental variables inside an I/O monitor or by observing the control of the physical system directly via a webcam.

### IV. GOLDi LABS CLOUD

Actually the GOLDi infrastructure is used within two running TEMPUS projects: Wider objective of the ICo-op project [6] is e.g. to empower university-enterprises partnerships in Armenia, Georgia, and Ukraine by modernizing engineering education based on remote engineering and virtual instrumentation; enhanced with transversal knowledge and competences at universities and offering contemporary methods of the vocational education and training for adults in enterprises. One of the specific objectives of the DesIRE project [7] is e.g. to create remote and virtual laboratories in the area of Embedded System in Armenia, Georgia, and Ukraine for distance and e-learning.

This means, that each project partner receives a complete remote lab. Totally GOLDi remote labs are running at ten universities in Armenia, Georgia, Germany, and Ukraine. One implementation problem we have had to solve is the maintenance of each partner remote lab:

- Any new functionality or a new firmware must be implemented manually on each partner website.
- Each institution has specific modifications according their own requirements.
- Each university has different network architecture.
- Each university has different remote lab configurations.
- To have access to an experiment of the partner labs, a separate user account on the corresponding partner website is necessary.

Each GOLDi partner has to handle the maintenance itself – supported by the Ilmenau GOLDi project team. We realized very quickly that this procedure is very ineffective.

We decided to reengineer the network of all GOLDi remote labs to a GOLDi cloud system [8, 9]. Available GOLDi Servers (it means available partner remote labs) are registered in the GOLDi cloud. They are highlighted colored as ready to be used on the central GOLDi website (see Figure 2).

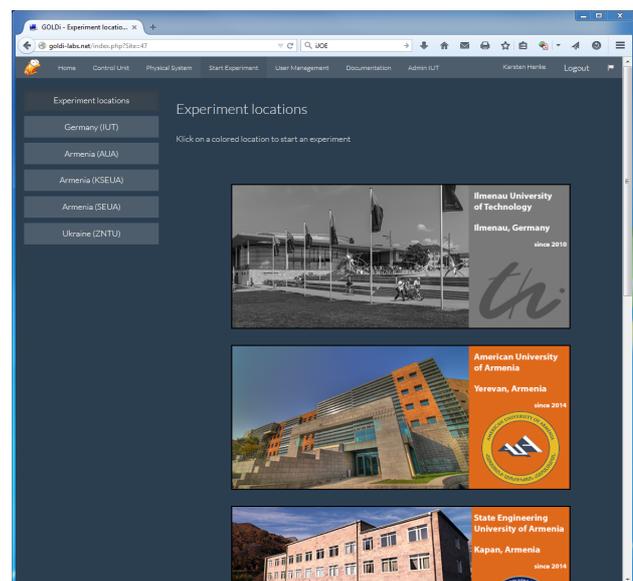


Figure 2. GOLDi cloud Website

The new cloud structure (see Figure 3) has the following advantages:

- Maintenance of the whole system on one central location: [www.goldi-labs.net](http://www.goldi-labs.net)
- All partner universities have the same GOLDi version.
- New functionalities are immediately available for all partners.
- Usage of all partner labs with one central [goldi-labs.net](http://www.goldi-labs.net) user account.
- The user can determine which lab has the lowest delay (best reaction time) regarding his current geographic position and internet connection.
- Overview about all running experiments in all partner labs worldwide with the possibility to observe these experiments.

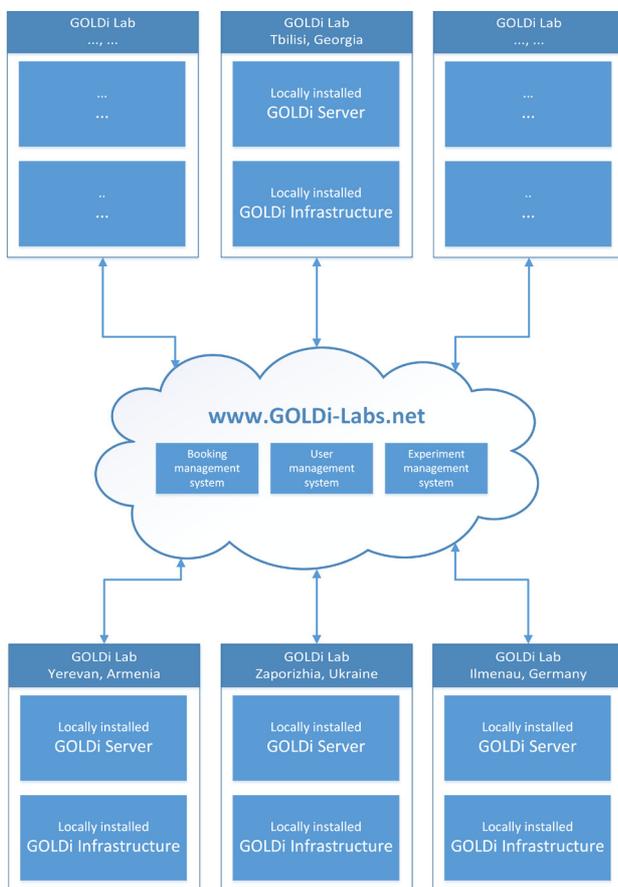


Figure 3. GOLDi cloud architecture

Each GOLDi client communicates with the GOLDi cloud for the central user and experiment management and the booking management. All privacy-relevant data of the cloud are located in the computing department of the Ilmenau University of Technology with highest privacy-requirements and will never be exchanged with the local GOLDi Servers of the partner institutions.

With the local GOLDi Server each client exchanges only the sensor/actuator signals during a running lab experiment directly.

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