NWACC – FINAL PROJECT REPORT

1) Project Identifiers

Title of project: **Hardware-in-the-Loop Robot Simulator for On-Site and Remote Education**

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URL of project Web site: http://www.uaf.edu/ece/remote-robotics/

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Statement of Project goals

The aim of this project is to develop a novel and remotely accessible Hardware-in-the-loop Simulator (HILS) system as a multipurpose, multilevel laboratory test-bed for undergraduate and graduate education in robotics, mechatronics and control. The proposed HIL architecture can be used for the real-time simulation of a variety of robotics and other electromechanical structures under a variety of control strategies and will be made accessible for both remote use via the internet and on-site use at the UAF Electrical and Computer Engineering Department. The state-of-the-art motion control and information technologies proposed in the project will provide a low-cost and highly efficient solution for the wide range of experimentation needs of both on-site and remote students/ researchers in the above mentioned engineering areas of interest, without the need for the actual physical existence of the electromechanical system that is being simulated, in the lab.

The project is a part of a larger NSF-CISE proposal grant. The specific goals of the whole project to be fulfilled within the NWACC grant are the following (as stated in our previous report):

a) Development of the HILS setup- hardware and software-, specifically for real-time robotics simulations.
b) Development of the client-server communication protocol to allow remote access to the setup via the internet.
c) Development of case studies for various robot configurations; such as, 2 degree-of-freedom (DOF) planar robot arm, PUMA 560 etc.
d) Development of control algorithms on the DS1104 motion control board, such as PID, PD, PD+ etc.
e) Preparation of the animation tool, which gives an animated representation of the results for the robotic configuration in consideration
f) Preparation of the website to serve remote students and researchers.

Teaching or research setting the project results were implemented:

In terms of teaching, the HIL setup is used in the PI's Fundamentals of Automatic Control, as a demo setup on which effects of various controllers, P, PD, PI, and PID are demonstrated. In the upcoming semester, it will be used in the PI's Robot modeling and Control graduate course. While in the former the HILS serves as an education enhancement for small projects to provide the students with some proof of practical results, in the latter course, it will serve as a constant laboratory tool to demonstrate important aspects of robot dynamics and control. The PI will use the setup also in her Modern Control Engineering and Digital Control graduate courses as a small projects tool.

In terms of research, the project set the basis of a Masters thesis, during which the project goals (a), (b), (c), (d), and (e) were accomplished. With the established setup and client/server communication protocol via the NWACC grant, the PI also applied for an NSF supplemental and international collaboration grant. The project, entitled " Bilateral Control of Robots with Time Delay Compensation" has just been accepted by the NSF-CISE and International Collaboration Offices. This part of the project will serve the development of the communication delay compensated bilateral control of two robotic systems via the internet. Currently, the developed client/server protocol is also being used in another Master thesis, which involves the remote control of the actual PUMA 560 to provide a very realistic evaluation tool for the developed HILS.

Discussion of Project Results

a) Development of HILS- Hardware:

The HIL robotic simulator consists of two motors coupled to each other. The first motor functions as the actuator of the motor in the joints of the robot arm in consideration; the second motor acts as the motor on which the load dynamics affecting this joint will be developed. While the first motor is chosen based on the actuator type in the joints of PUMA 560, the second motor (load motor) is chosen as a direct-drive motor

(DDM) based on high performance features such as accuracy and fast response. The particular choiceof motors allow the on-site/remote user to make very realistic simulations of robotic systems, such as PUMA 560.

Development of HILS Software

In this HILS system, the DS1104,- a product of dSPACE, is used as the motion control unit (MCU). The DS1104 card is downloadable from Matlab/Simulink and has been used for the development of robot dynamics models for 2 DOF and PUMA 560, as well as control algorithms, such as PID, PD, and PD+.

b)Development of Client-Server Communication Protocol

The main program that establishes the communication between the client and the server is written in C/C++ programming language with the use of wxWidgets. MATLAB Engine is used to establish a link between MATLAB and the C/C++ code. For data capturing, a code is written in Python programming language, which is compatible with ControlDesk. The ControlDesk software that is a product of dSPACE, is used for signal monitoring and tuning.

c) (d) Case studies for robot dynamics and control:

Case studies have been prepared for the PID and PD+ control of PUMA and SCARA type 2 DOF robots and are available for both on-site and remote use for a variety of reference trajectories.

e) Animation

Finally, a visual simulation is prepared for the 2-DOF planar robot arm HILS to help the client visualize the behavior of the system. This visual system is prepared with the MATLAB V-Realm Builder. As the final step of the 2-DOF HIL planar robot arm simulation, the visual simulation is sent to the client.

Website

General information on the project and remote access to the HIL setup in the UAF's Robotics lab is provided via our website at http://www.uaf.edu/ece/remote-robotics/

All the project goals within the NWACC grant were fully met, also providing support to the ongoing NSF project as well as the new NSF project mentioned above.

Impact of project on future goals:

The project will serve as basis to our new project on bilateral control, which will benefit strongly from the established HIL setup as well as the communication protocol.

The HIL setup in the project will also serve our Hybrid Electric Vehicle(HEV) Project, as both the setup and the communication protocol will be used for allowing also remote access to the HIL setup for HEV experimentation at UAF.

Publicity

Due to the remote component of the project, the results are already disseminated and available to all internet users all over the world. Our project and NWACC contribution is already advertised in several IEEE conference presentations and one journal paper to be presented to IEEE IES Transactions.