Telemark University College (Norway) / Finn Haugen (finn.haugen@hit.no)

5. December 2009

Laboratory assignments based on LabVIEW and NI USB6008 I/O device

We believe that students get a much deeper understanding of theoretical methods by implementing the methods in practical applications. To this end, we have developed a number of laboratory assignments which are a part of different courses in our master study at Telemark University College. We have standardized the implementation tools as **PCs** (laptops or desktops) with National Instruments **LabVIEW** and the inexpensive **NI USB 6008 I/O device**, but MATLAB and SIMULINK are also used to some extent [1] [2] [3] [4]. As lab stations we use **air heaters** (7 copies) [7] and **water tanks** (6 copies) [8], which are "desktop" lab stations. Due the large number of lab stations, we can run labs in parallel, and with small student groups. Although the final aim in the assignments is to apply the solutions developed by the students to the physical system, the students are required to apply their solutions to simulated processes first. The feedback from the students on these assignments is very positive.

The following laboratory assignments have been designed:

- **Temperature control system** where the students download an almost complete LabVIEW program and then add a few blocks to the program to obtain a complete progam for temperature control of an air heater. [14] [7]

- **Level control system** where the students download an almost complete LabVIEW program and then add a few blocks to the program to obtain a complete progam for level control of a water tank. [15] [8]

- **Implementing an industrial PID controller and a measurement filter** from scratch in C code with practical features as bumpless transfer, anti integral windup, and reverse/direct action. The controller is applied to either the water tank or the air heater. [5] [6] [9]

- **Hardware-in-the-loop simulator** based on an industrial PID controller (Fuji PGX) controlling a simulated process. [6] [10]

- **Soft-sensor (state estimator)** for estimating an unknown outflow from water tank using alternative various methods: "Direct estimator" (solving the model for the unknown variable), a Luenberger observer, and a Kalman filter. The flow estimate is used in feedforward control of water level. [6] [11]

- **System identification** of air heater in the form of a discrete-time transfer function using a subspace identification method (n4sid in MATLAB). A temperature controller for the simulated process is then tuned in SIMULINK, and a practical temperature control system is then implemented in LabVIEW. [6] [12]

- **Model-based predictive control (MPC)** of air heater, using the MPC controller of LabVIEW [6] [13]

References:

1. F. Haugen, *Introduction to LabVIEW Control Design, System Identification and Simulation Tools*. National Instruments Days, Drammen, Norway. 25 April 2005.

2. F. Haugen, *Examples of Student Assignments on Modeling, Simulation, and Control*. National Instruments Days, Drammen, Norway. March 8. 2007.

3. F. Haugen, Fjelddalen E, Edgar T., Dunia R., *Demonstrating PID Control Principles using an Air Heater and LabVIEW*, CACHE News (Computer Aids for Chemical Engineering), Winter 2007

4. R. Dunia, Edgar T., Haugen F, *A Complete Programming Framework for Process Control Education*. Submitted to the 2nd IEEE Multi-conference on Systems and Control (MSC), September 3-5, 2008, San Antonio, Texas (USA)

5. F. Haugen, *Basic Dynamics and Control*, ISBN 978-82-91748-13-9, TechTeach, 2009

6. F. Haugen, *Lecture Notes in Models, Estimation and Control*, ISBN 978-82-91748-14-6, TechTeach, 2009

7. F. Haugen, *Air Heater*, http://home.hit.no/~finnh/air_heater/, 2009

8. F. Haugen, *Water Tank*, http://home.hit.no/~finnh/dok_tankmodell/, 2009

9. F. Haugen, *Lab assignment: Implementation of a control system*, http://www2.hit.no/tf/fag/sce1106/2009/project/project/, Telemark University College, 2009

10. F. Haugen, *Lab assignment: Hardware-in-the-loop (HIL) simulation*, http://www2.hit.no/tf/fag/sce2006/2009/hil_sim/, Telemark University College, 2009

11. F. Haugen, *Lab assignment:Soft-sensor (state estimator)* http://www2.hit.no/tf/fag/sce4206/2009/softsensor/, Telemark University College, 2009

12. F. Haugen, *Lab assignment:System identifiaction* http://www2.hit.no/tf/fag/sce4206/2009/system_ident/, Telemark University College, 2009

13. F. Haugen, *Lab assignment:Model-based predictive control (MPC)* http://www2.hit.no/tf/fag/scev3106/2009/projects/mpc/, Telemark University College, 2009

14. F. Haugen, *Lab assignment:Temperature control of air heater* http://www2.hit.no/tf/fag/pef3006/2009/lab_temp_control_labview/, Telemark University College, 2009

15. F. Haugen, *Lab assignment:Level control of water tank* http://www2.hit.no/tf/fag/pef3006/2009/lab_level_control_labview/, Telemark University College, 2009