

On the aim of teaching, how to reach it - and an example

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ABSTRACT: In the paper, the aim of teaching is defined as facilitating for students to learn how to solve real problems. Implications of this definition is discussed, with an example of an implementation in a university course about automatic control.

1 INTRODUCTION

After thirty years of experience as a teacher of courses in automatic control at both the undergraduate and graduate level and instructor of courses for practitioners in industry, I still ask: “Am I teaching well enough?”. My own answer is “no”. So: How can I improve? To improve my teaching, I need a definition of the aim of teaching, and then find strategies to reach that aim. This is the main topic of this paper.

2 ON THE AIM OF TEACHING AND HOW TO REACH THAT AIM

Different teachers may define this aim differently. I have found the following definition useful:

The aim of teaching is to facilitate for students to learn how to solve real problems.

Then, how to facilitate for learning how to solve real problems? It is my view that such learning requires work with real, physical systems.

In teaching of basic automatic control at universities, analysis and design methods based on the frequency response theory has been prevalent. However, in my opinion, using this theory to introduce the basic concepts of automatic control is unfortunate because of its lack to express real-world responses in the time-domain. A more fruitful theoretical basis is theory related to differential equations. Differential equations are useful as they may stem directly from mechanistic modeling (i.e., material balance, energy balance, laws of motion, and electrical laws), and they can also easily be defined to represent standard dynamics as time-constant dynamics and integrator dynamics.

Dynamic simulators may be very useful in teaching as well as in real automatic control projects. Essentially, a simulator is the execution of some numerical solution algorithm of the differential equations making up the model. My experience is that the simplest numerical algorithm, namely the Euler Explicit (Euler Forward) algorithm, is usually sufficient.

However, a simulator, although useful, can of course not fully substitute practical experience. Consequently, I regard practical work as necessary for learning how to solve real control problems.

Obviously, to include the practical aspect in the teaching, it is necessary that the teacher has personal experience from solving practical tasks. This experience may be obtained from personal involvement in research and development projects.

3 EXAMPLE FROM THE UNIVERSITY COLLEGE OF SOUTHEAST NORWAY

At the University College of Southeast Norway (USN), the teaching of a basic control course (Haugen, 2016) was changed substantially from fall 2015 and on with the inclusion of nine laboratory exercises based on desktop-size air heaters for temperature monitoring and control, accomplished in groups of two or three students. The exercises are merged with traditional and video-based lectures throughout the semester. Twenty-six identical rigs built in-house (Haugen, 2010) allow that all groups work with the same exercise simultaneously, see Figure 1, 2 and 3. The number of students is approximately 70 (when two similar courses have common exercises). The students use laptop PCs running National Instruments LabVIEW. Each assignment lasts 5 hours. Each group must hand in a report, and the teacher sends comments to the reports within a few days.

A mid-term evaluation Fall 2016 conveys that the extensive use of laboratory exercises is very well received by the students at USN.

The laboratory assignments cover the following topics. (A short version of the above list has also been presented in (Komulainen et al., 2016).)

1. *Manual temperature control, monitoring, and data logging to file.* In this assignment the students learn the basics of using a computer to control and monitor a physical system.
2. *Implementation of a dynamic process simulator of the air heater.* The mathematical model that is the basis of the simulator is a time-constant with time-delay model with default model parameter values, provided by the teacher.
3. *Adaptation of the mathematical model to the real process.* The model adaptation amounts to estimating parameter values of the time-constant with time-delay model. This is realized using the “brute force” or “gridding” least squares method implemented in nested for-loops. Figure 4 illustrates the result of the model adaptation (apparently, the model represents the physical system well).
 Comment: The gridding method is a straight-forward approximative, global optimization method which is applicable to many simple optimization problems, e.g. PID controller tuning, steady-state process optimization of design and process operation, parameter estimation, etc.
4. *Implementation of feedback controllers from scratch.* The controllers are a discrete-time proportional-plus-integral (PI) controller and an On/off controller.
5. *Implementation of a measurement lowpass filter.* The filter is a discrete-time time-constant lowpass filter, also denoted the EWMA filter (Exponentially Weighed Moving Average), which is the typical filter algorithm used in industrial controllers.
6. *Controller tuning.* The tuning methods are the Skogestad tuning method (Skogestad, 2003), and the Ziegler-Nichols method (Ziegler and Nichols, 1942) and one of its modifications (Haugen and Lie, 2013). These methods are applied experimentally in the lab assignments.
7. *Control loop stability.* Hitherto, a qualitative analysis is included, including the stability impact of controller gain (both absolute value and sign), integral time, and filter time-constant. Starting with Fall 2017, an experimental estimation of gain margin and phase margin (Seborg et al., 2011) according to the procedure described in (Haugen and Lie, 2013) will be included.
8. *Feedforward control.* The students are to implement an experimental, table-lookup based feedforward controller with air flow (disturbance) measurement as input signal and heater control signal as output signal.
9. *Industrial PID controller.* The industrial PID controller (Fuji PGX5), instead of the LabVIEW-based control system, is used for temperature control.

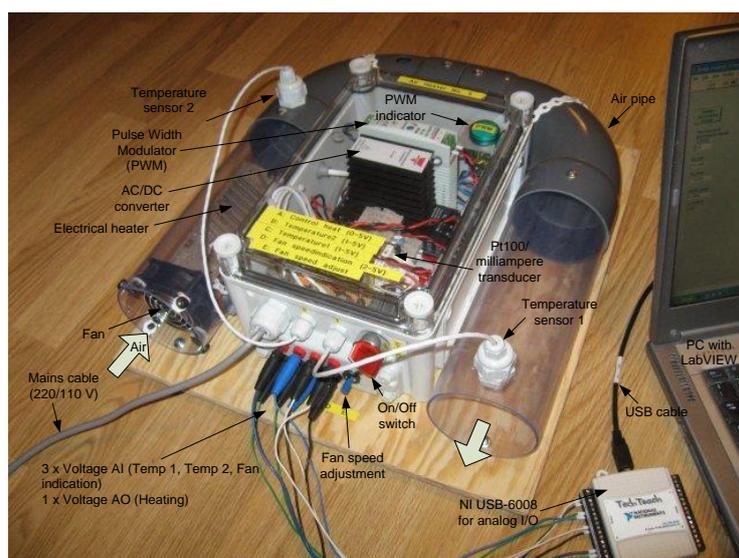


Figure 1: Air heater laboratory rig for temperature control. The voltage control signal manipulates the power delivered by the electrical heater. The outlet temperature is measured by a Pt100 element. The air flow through the pipe can be manually adjusted, representing a (measured) process disturbance.



Figure 2: The air heater rigs on the shelf.



Figure 3: Student groups working on laboratory assignments.

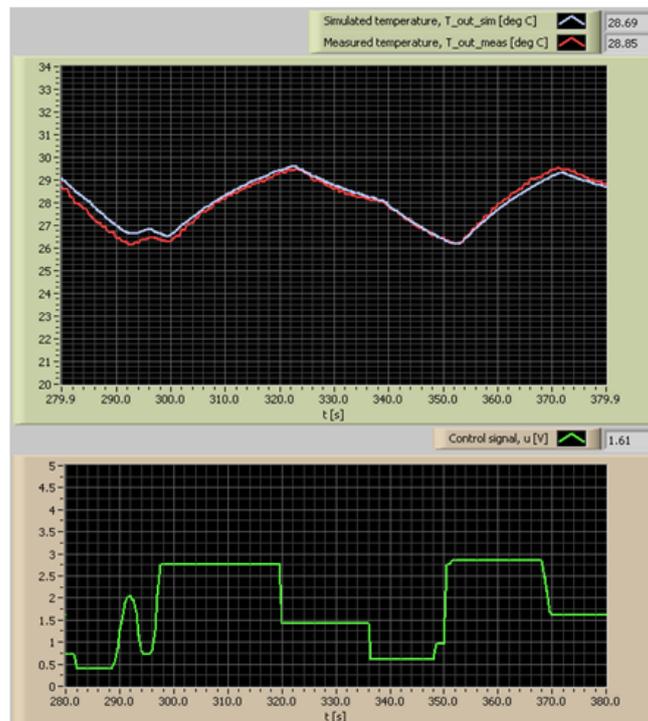


Figure 4: Result of adaptation of time-constant with time-delay model to the real air heater. Lower plot: Control (input) signal to the electrical heater. Upper plots: Real (measured) outlet temperature (red curve) and simulated outlet temperature (blue curve).

4 SUMMARY

In the paper, the aim of teaching has been defined as facilitating for students to learn how to solve real problems. Implications of this definition are the inclusion of practical assignments in relevant courses. An example has been presented where a relatively large number of practical assignments is merged with theoretical lectures in a course about automatic control. In the example, the implementation relies on the students working simultaneously, or in parallel, on a large number of identical laboratory rigs (desktop-size air heaters).

ACKNOWLEDGEMENT

The practical support by senior engineer Eivind Fjelddalen, University College of Southeast Norway, in constructing the air heater lab stations is highly appreciated.

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