TEACHING DATA ACQUISITION SYSTEMS – A HANDS-ON APPROACH

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Abstract - Sugestive for this paper is the students' expression that says „the first 6 years are difficult until you reach the third school year". And the rhymes are not very far from the truth. In this moment the curriculum sets for the first two years only fundamental courses as: math, physics, mechanics, electronics, computer programming. In the last two or three years there are special courses, that are meant to transform the good theoretical base student into an inventive and skilful engineer. The partition of the education process in two separate successive stages: base preparation and technical education seams fair, theoretically speaking. Unfortunately our experience has shown that things aren't going the right way because the lack of a professional horizon. Theoretical base preparation, time and energy consumer, barely allows the student to dream of technical accomplishments and to fulfill their hopes. Students carry on the first stage of preparation without foreseeing the MP3 encoder in the study of Fast Fourier Transform, a dancing robot control in the study of differential equations or an environment parameters monitoring system in thermodynamics. More than that, an important percent of the students is losing the enthusiasm and sometimes the belief that they will achieve what they have hoped.

1. Introduction

After a long time of poor feedback from our students, we decided to change not only the information we present in our courses, but also the way we teach. In a technology world that changes at a very fast pace, the theory-heavy lectures of different disciplines followed by little relevant practice bore students. Professors have to keep them interested by proving that engineering is not another (difficult) way to look at mathematics, but an interesting, creative and always innovating field.

How can we reinvent the engineering education? How about having a classroom full of diagrams, Lego blocks, tools and laptops? How about making them solve problems using their original ideas, and then correct their solutions, rather then giving them prefabricated solution templates? We are not ignoring the chalk and the blackboard, but we change their importance and place in teaching. There is a definite need to practice more to apply the theory, leaving behind the expression "first theory, then practice". Students need to learn the interdisciplinary study and the teamwork, and that can only come out of practice. Professors need to encourage students to design solutions, and then give them the theoretical means to improve these solutions according to more and more complex theory.

In this paper we show how these changes can be applied to a real course in the curriculum of POLITEHNICA. The topic is "Data Acquisition and Processing Systems" (DAPS), and it is taught as a special course in the 8th semester.

2. Data Acquisition and Processing Systems – the old way

Simply put, data acquisition is a transformation of real world data in a computer acceptable form. Data acquisition and processing systems (DAPS) are solutions that have combine measurements accuracy and finesse with the computing power of microprocessors. The data acquisition block and the processing block, together, allow the user to quickly grasp the evolution of the tested process. Furthermore, modern acquisition systems can even provide feedback commands to the process itself by using specific local processing algorithms.

2.1. Course Objectives

Data acquisition and processing systems (DAPS) are important components in process control systems. They can be automation solutions for low complexity processes. For more complex processes, where the control is either centralized or distributed, acquisition and distribution modules represent subsystems directly related to the process.

The main course topics are: DAPS as embedded systems or as parts of control systems; functional and constructive analysis; classifications using structure and utility criteria; hardware structure and DAPS main functional blocks; dedicated software programs; characteristics and performances analysis; DAPS selection criteria; implementing solutions; PLC and PC as DAPS.

The course, previously organized as a series of lectures, had the main goal of teaching students how to build specific data acquisition systems or how to choose available off-the-shelf solutions starting from the application requirements. The labs have been focusing on using various DAPS, with different complexities and characteristics. All these goals had to be reached in 42 course hours and 28 practical work hours. Course and laboratory extended curricula are presented in table 1 and table 2.

Chapter	Content	Nr. of hours
1. Introduction	The definition of DAPS; DAPS in complex control systems. DAPS clasification according to the working conditions.	3
2. Numerical measurement system	DAPS for favorable working conditions. Numerical measurement. Measurement systems with standard interface IEC 625.	12
3. Industrial DAPS	DAPS for unfavorable working conditions. Industrial DAPS structure. Functional and constructive classification.	3
4. DAPS structure	Introducing the components of a DAPS: conditioning elements, multiplexers, Sample/Hold devices, Analog Digital Converters and Digital Analog Converters, Dedicated microcontrollers. The analysis of the components performances	10
5. Embedded equipments	Intelligent transducers; intelligent execution elements;	5
6. Distributed DAPS	The definition of distributed DAPS. Network communication with fieldbuses for distributed DAPS. BITBUS fieldbus.	9
		Total: 42

Table 1: Course curriculum

1.	Plug-in Digital Acquisition and Processing Systems with hardware and software Analog-Digital Converters	6
2.	DAPS for numerical Inputs/Outputs	2
3.	The use of FPGA-s for implementing DAPS	2
4.	The use of microcontrollers and dedicated microprocessors for DAPS implementation	6
5.	Barcodes and RFID based Data Acquisition System for products identification	2
6.	The use of PC-s as DAPS-s. The use of serial and parallel interfaces for data acquisition	2
7.	The use of PLC-s as DAPS.	2
8.	DAPS with BITBUS	2
		Total: 24

Table 2: Aplications

The teaching activities were performed in the classical way - one lecture (3 hours) per week and one lab (2 hours) per week. Students did not interact properly, they were not enthusiastic and not involved in the lab activities. There were no new ideas and challenges that either part (professors and students) had to develop and answer. Thus, inspired by the idea from the Olin College, we moved on to a different approach, presented in next sections.

2.2. Course Evaluation & students feedback

The examination of the course was very theoretic, and most students were not able to really show their abilities in connecting the practical work with the theory we were teaching. Thus, the exam results were poor and, even worse, we were not sure that the grades were actually reflecting the levels of knowledge in DAPS that the students had acquired. This added to our motivation in replacing the classical, "theory-first, practical-afterwards" to a more hands-on approach to data acquisition.

2.3. When to Teach DAPS?

Another issue that we have to struggle with in terms of teaching DAPS is the positioning of the course in the curriculum schedule, too late (in our opinion) for such an important engineering topic. However, the course was scheduled in the 4th year mainly because of the prerequisites that the students had to go through, as they needed lots of mathematical and physics knowledge to completely grasp the theoretical parts. If we move on to a more hands-on approach, the course can be safely moved into the 2nd year, when students are still very interested in "how things work". Furthermore, their interest for acquiring more theoretical knowledge to understand how these DASPs work will probably help with their somewhat weaker motivation for theoretical topics like mathematics and physics.

3. Data Acquisition and Processing Systems – a new way

Due to all the issues described in the previous section, we have decided to change the teaching method. Thus, starting this year, we propose a different approach, based on the mutual cooperation between student and professor, rather than on a uni-directional flow of information from professor to student.

We have already done some steps towards this new approach:

- We have changed the ratio between theory and practical work. In different words, we made students ask for theory in order to solve the projects we were proposing. The students have projects, but do they know how to solve their problems? As the student goes deeper and deeper into the problems of the project, he will be faced with some unknown territory, and more math and more physics may be needed.
- We have changed the ordering of teaching: we start with labs, and gradually move to lectures.
- We have evaluated „in real-time" the students knowledge level and skills, thus being able to tune the lectures and labs.
- We have replaced the „one-man-show" model of one professor with a more distributed approach, combining the competencies of several professors (both for labs and lectures) towards the overall course success.
- We have asked students to work in teams
- Lab work is completely changed: students have to build data acquisition systems, test them, experiment on them, and then gradually improve them either because (1) the results are not good enough, or (2) the specifications we are giving them are getting more complex.
- We have changed the weights of the practical work in the final grade, focusing more on the creativity and efficiency of the student teams.

3.1. Stepping on the new way

Applying the new strategy meant to us three important changes:

- we had to formulate new course and laboratory curricula;
- we had to change the laboratory activities and schedule;
- we had to implement the multi-professor strategy and for this we had to convince some of our colleagues to help us with their lectures.

3.1.1. The new curricula

Because the new method means “to do and then to learn” the laboratory curriculum got a new contents and a new form. It contains five projects the students had to solve. They are:

1. Op-Amp gain linearity measuring system built using HPIB programmable devices;
2. Op-Amp based simple circuits (inverting amplifier, noninverting amplifier, LPF, integrator, rectifier) functional characteristics testing system;
3. railway system traffic supervising system;
4. aquarium parameters measuring system (temperature, pH, solved oxygen)
5. an autonomous vehicle monitoring system.

The schedule of the projects is presented in table 3

Project number	Date the students got the subject	Date the students had to present the project
1.	Week 1	Week 4
2.	Week 3	Week 6
3.	Week 5	Week 8
4.	Week 7	Week 10
5.	Week 9	Week 12

Table 3 The projects schedule

The course curriculum was a problem because we did not know how the students react to the new method. At the beginning of the semester we proposed ourselves to present the main topics of the old curriculum, emphasizing their relations with the projects.

3.1.2. Project oriented laboratory

Solving projects means anything else than doing laboratory works. So, we had two problems: the hardware and the software resources and the laboratory schedule.

The resources were partitioned in several categories:

- programmable devices;
- transducers, sensors and measuring devices;
- plug-in data acquisition boards that could be mounted inside a PC;
- central processing units: developing boards with microprocessors, microcontrollers and FPGA modules, LEGO type processing units, micro PLC and PLC, personal computers;
- software packages and drivers.

3.1.3. Multi-professor concept

Our idea liked to some of our colleagues and so we succeeded to have rather always the appropriate specialist teaching the lecture.

4. A case-study : Embedded Systems

An interesting project for all students was to provide a happy environment for a bunch of fishes in an aquarium. It had to be implemented as an embedded system that monitors the life parameters in the fish environment, which was a nice, real-life challenge. For building this system, the students had access to the following building blocks: transducers, PC-board pluggable DASs, microcontroller units/boards, LEGO units, integrated circuits of their choice, programmable automata and all the required software drivers. The experiments were done successfully on a set of 7 fishes and their 50x40x100cm aquarium. We are happy to report that all the subjects of our experiments are still alive.

From all the students enrolled, 84% had solutions, and 78% were working solutions, ranging from simple PC-board based solutions to specific HW-based solutions. Typical problems that the students encountered and which required additional lectures were related to digital-analog conversions (HW and SW techniques), signal processing circuits, DAS noise reduction techniques.

5. Conclusion

The results of the new method were really satisfactory – in our opinion, especially as a first try. Students like the course much more, and they were much more involved in both the practical and the theoretical parts of the course. While in the previous lectures we had no questions for the theoretical parts, the connections between formulae and their real problems became easier to spot, and then the motivation to understand and learn the formula became implicit. Furthermore, by actively including the professors in the project solving activities, the cooperation between the sides was very fruitful, and it made both sides happier: by being colleagues, the students seemed smarter, and the professors younger. Finally, the ideas we have gathered made us think that some embedded systems companies would pay good money for the patents.

Of course, there were some troubles as well. First, we had to find the optimal balance between the project workload and the students abilities, as some of the ideas, although good, may have caused too big of an overhead, and they would have been not feasible. We have filtered those out by indicating the problems and proposing various workarounds. Furthermore, the schedule and the lab resources became important issues, as practical work can no longer be restricted to 2 hours an week.

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