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Interdisciplinary project-based learning at master level: control of robotic mechatronic systems

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Abstract: This paper presents a project based learning at master level with strong interdisciplinary elements. Within the course of ICT and Mechatronics at Ghent University, the classical laboratory experiments do not present a suitable challenge for the students. In order to motivate them and rise their interest in the field, challenging smaller projects (i.e. control of a mechatronic system) are introduced in the curriculum. During the projects, the students have to use their skills such as programming languages (e.g. C++, Java etc.), communication, basic control techniques, etc. As an outcome, the students acquire the appropriate competences (e.g. ability to understand a mechatronic system, a motion control strategy, etc.) needed to deal with this kind of problems at industrial level.

Keywords: Project based learning, robotics, mechatronics, lego cars, group work.

1. INTRODUCTION

All over the world, especially in Europe due to the Bologna process, several changes at university level have been encountered (-, 2015a; Musselini, 2004). Most of the European universities take the opportunity of the Bologna process to revise their curricula and to restructure the educational program. Within Ghent University, the classical 5-years engineering study program has been converted in a 3-years Bachelor and 2-years Master. Each year, the number of students enrolling for a bachelor or a master program has increased significantly. In 2014, more than 900 students have started their studies at Faculty of Engineering and Achitecure at Ghent University. The end of the bachelor degree (after three years) is marked by an interdisciplinary project work where the students become familiar with the practicalities of the theory they studied hitherto. Almost the entire number of students choose to continue their studies at master level, where they acquire specific expertise in their choice of specialisation. Within the choice of Control Engineering and Automation, several courses are introduced with new emerging learning tools.

It has been shown that for engineering students, in order to provide a better understanding of the theory, the student needs to apply it in real-life experiments (Dormido, 2004). However, the infrastructure necessary to perform laboratory experiments is not always available and therefore other solutions have to be invented, leaving room for creativity of both the tutor as well as the student (Rossiter, 2013).

As presented in (Ionescu et al., 2013; Chevalier et al., 2015, accepted for publication, 2016) one solution implemented at Ghent University to address the problem of practice for large groups of students (i.e. typical bachelor years) is to use remote lab applications. In this way the students can use the infrastructure available in various locations in the department/faculty/university to apply their theoretical knowledge. Other successful solutions have been also proposed such as applied exercises (Pasamontes et al., 2012) and problem based learning (Barrows, 1986; Padula and Visioli, 2013). Moreover, the students are not just applying the theory they also learn how to work in teams (i.e. task management, leadership, etc.), also known as active learning (Acevedo et al., 2008; Prince, 2004).

In the last decades the technology advanced significantly, but also the attitude of the students has changed during last years and all these aspects of the new academic environment have a great impact on teaching activities. Nowadays, the new technologies (e.g. computers,smart phones, tablets) are highly accessible to the students (Lindsay and Good, 2005; Rossiter, 2013). Moreover, Ghent University has subscription to multiple on-line libraries and the students have access to high quality scientific papers which offer the possibility to be always up-to-date with the latest news. Hence, the professors have to be also updated with the latest technology in order to offer the best motivation to the students. Something perhaps worth mentioned here is that this new style of teaching has increased the workload of the teacher at the benefit of the student.

This paper presents the development of project based learning within the course of ICT and Mechatronics given

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at Ghent University; the full description of the course is available online (-, 2015b). By performing these experiments the students will have to apply their knowledge on motion control, programming languages, communication protocols, in order to achieve the final goal of the project. At the end of the projects, adjacent to the initial skills, they will acquire competences such as design and implement computer-based motion control strategies, etc. Teams and individuals will be evaluated for: project results, depth of execution, presentation skills, motivational aspects of their choices and a peer assessment.

The paper is structured as follows. In Section 2 the academic context and project description is presented, along with a short overview of the course and a detailed description of the projects. In Section 3 the hardware used for the project is presented. Section 4 defines the control problem addressed in each project. In Section 5 the results and overall assessment are detailed followed by conclusions.

2. ACADEMIC CONTEXT

The ICT and Mechatronics course studies the interaction between information-processing systems and the physical world in the context of mechatronic *robotic* systems. The course is conceived as an overview of concepts and methods that play important roles on the information processing of mechatronic applications. The course consists of three main parts. Firstly, the basic structure of microprocessors is shortly described, emphasizing the elements that allow real-time reaction and processing of multiple tasks. Secondly, modelling and steering of complex robotic systems is addressed. More specifically, it reviews the basic methods for representation and steering/planning in a more general scope than the already known traditional linear stabilization. Thirdly, it considers the processing of measured information in a diversity of contexts, and details on how the associated information-handling principles also applies to telecommunication. The course addresses the following topics (selected):

- ICT systems set-up for mechatronics;
- Advanced actuation techniques;
- Sensor properties and types, active sensing;
- Motion control: system identification, discrete-time PID control, autotuning of PID controllers, fuzzy control strategies.

The master course projects are closely related to the course content and aim to aid the students in the process of learning how to deal with control of robotic and mechatronic systems (Astrom, 2006). The number of students enrolled for this course is about 100. To ensure a good management several groups have been created and each group consists of 5-6 students. Since *task management* is also a very important competence that the students should have at the end of their studies, a follow-up process consisting of three steps was implemented. Each group had to hand-in two intermediary reports and one final report. The role of the intermediary reports was to track the progress of the students and simultaneously to have an overview of the workload of each student and of the task distribution for every team member. Wherever necessary, the tutor would intervene. Moreover, the students were encouraged to use forums to ask questions related to the projects among themselves and the tutor would also intervene whenever necessary. In this way, the students are motivated to help each other by giving answers/suggestions/ideas to the faced problems.

The competences aimed at the end of the course are:

- understand how basic components of complex mechatronic systems work, especially on the ICT side
- name relevant techniques and recognize the dangers for multiple-task management
- understand basic communication techniques: setting up communication, choosing information channel and information content
- discriminate between different task organizations: layers, parallel threads, object oriented
- represent simple motion systems with matrix groups and realize their limitations
- divide simple plans by backwards induction.
- design and implement computer-based motion control strategies
- understand the reasoning and assumptions behind correct data interpretation, information extraction and artificial intelligence / machine learning
- propose, analyze, select and implement hard- and software solutions for sensing and actuation in a newly encountered mechatronic system
- efficiently report on project advances, clearly describe technical solutions.

3. DESCRIPTION OF THE PROJECTS

To cover the entire curricula of the course, four different classes of projects were proposed to the students. These projects are briefly defined below:

(A) design of an Antilock Braking System (ABS) on a LEGO racer car (3 groups were assigned for this project)
(B) two-track line follower system which can avoid obstacles present along the line (5 groups were assigned for this project)
(C) path planning task and sensor fusion on a two-track system (4 groups were assigned for this project)
(D) mechatronic implementation of a movable robotic arm including the design and implementation of a control strategy (4 groups were assigned for this project)

Each project class made use of all the knowledge acquired during this course, and from other related courses, while focusing on specific aspects of the course.

The competences that are obtained within this interdisciplinary project, for each class of project are given in Table 1. In order to have the feedback with respect to the experience of the students while developing this type of projects, a set of questions have been addressed to all the students and the average cost are given in Table 1.

3.1 Project type A - Design of ABS

Each group of the students assigned to this project class is provided with a LEGO racer car called Dirt Crusher. The car has a battery pack and two motors in the back,