A MECHATRONIC DESIGN PROJECT INTEGRATING MEASUREMENT, SIMULATION AND TRANSDUCER TECHNOLOGY

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Abstract. A project-oriented course is described in which teams of students learn to apply knowledge from lectures on measurement, system simulation and transducer technology by creating in a structured way original mechatronic systems. Starting point of the project is a specific transducer that first has to be fully characterised by measurements and modelling. A next step is the design of a mechatronic system using this transducer. The design must be evaluated, simulated and finally built, validated and demonstrated. Students follow in a creative atmosphere a strict design trajectory while learning to act in a team (4 persons), to organise themselves, and to be successful despite deadlines (2 weeks) and limited resources.

Keywords: measurement, mechatronics, transduction, education

1 INTRODUCTION

The mechatronics design project described in this paper aims at knowledge integration and the combined application of the subjects from three courses: Measurement Science (MS), Engineering Systems Dynamics (ESD) and Transducers and Mechanics (TM). These courses are part of the second year undergraduate program of the Department Electrical Engineering at the University of Twente. The course on MS focuses on measurement principles, transducers and processing of measurement signals. ESD deals with the modelling and simulation of physical systems and uses bond graphs as the modelling tool because of its general applicability (irrespective of the physical domain). The core of the course TM is the physics of transducers (both sensors and actuators) with emphasis on transduction from and to the mechanical domain. All three courses deal with information processing systems but from different viewpoints.

The major target of this common project is to stimulate students in applying knowledge as obtained from the various courses in a joined manner, by designing a technical system comprising at least some act of transduction. Four students build up a design team for this occasion and each team has to design, realise and demonstrate a laboratory prototype of a system following their own imagination. The project schedule is quite strict, running through precisely defined phases marked by specific milestones.

2 THE DESIGN PROJECT

The design project is organised similar to what students might expect in their later profession: a multidisciplinary team, strict deadlines, lack of knowledge about particular aspects of the assigned task, restricted resources. They do have basic knowledge, but still unexploited and fragmented. How to use such pieces of knowledge and to explore new sources of information to solve a particular problem? These competencies which any designer should possess and further develop are trained in this design project, midway the second year of the undergraduate program.

The teams are built up by the project supervisors: the team composition is not free to avoid unwanted biasing within a team. To each group a particular transducer is allotted as the starting point of the design trajectory that has to be followed. This transducer (for instance a electric motor, the voice coil from a disk drive, a loudspeaker) will be used as a basic element in an later design, and must therefore be characterised in order to fully understand its behaviour. The characterisation is based on a model (bond graph representation) of which the parameters have to be determined experimentally through measurements.

Meanwhile, as a result of brain storm sessions, the team has conceived various ideas about a new mechatronic system to be designed using the available transducer. The best idea is transformed into a coarse design, and by simulation the feasibility of the idea is tested. Upon approval of the supervisor, the team proceeds with a detailed design which again is validated by simulation. Next, when the feasibility of the detailed design has been proven the realisation phase starts, followed by testing, evaluation and comparing the system behaviour with the simulation results. At the end all teams give a demonstration of their system and respond to questions from the supervisors. These demonstrations are recorded on video for later evaluation.

The design cycle for this project is based on [1], in which the next steps are distinguished.

- ◊ *Conceptual design*
- ◊ *Preliminary design*
- ◊ *Detailed Design and Development*
- ◊ *Production / Construction*
- ◊ *Operational use / Maintenance*
- ◊ *Retirement*

Obviously, the last two steps are left to the responsibility of the students. Actually these phases are replaced in this student project by a demonstration. At the end of the project students are allowed to keep their system.

Each phase concludes with a design review, which in some cases should be written down in a report, to be examined by the teaching staff. Figure 1 shows a timing diagram of the design cycle as been scheduled in the 2000-2001 program. The graded colours in this diagram symbolise the vague borders between the various phases. However, the reports should be submitted before a strict deadline.

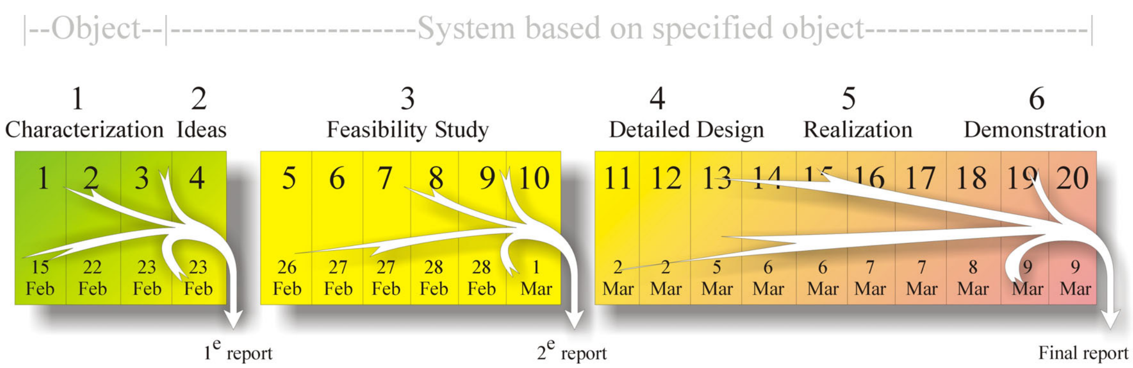

Fig. 1 The design cycle and timing for the program 2000-2001

The students can prepare this project by consulting various documents put on the Teletop web pages of this project [2]. Students have access to these pages after subscription. They can put their reports and any other material on a special spot in these pages. Teachers have access to these pages, and can view or download the student documents for further evaluation. Teletop also allows email individual and in groups communication between students, teams and teachers.

In one of the documents the student can find detailed information on the various design steps. Moreover, special questions are formulated as a guide for the student to follow the track and not to skip essential parts in the design cycle. An example to illustrate this service is the next list of questions and clues (shorted) about the characterisation of the transducer (measurement task).

- ◊ Is the transducer influenced by the measurement system? Try to minimise loading errors.
- ◊ The transducer is described by a two-port model. When measuring at one port, what to do with the other port? Does it make a difference?
- ◊ How accurate are the measurements? Quantify the errors and discuss their relevance.
- ◊ Which of the parameters can be determined directly by a measurement? Which are not accessible by a measurement but should be calculated from other parameters? How, and what are the errors in the resulting values?
- ◊ Compare the measurement results and the simulation results; keep in mind the following picture displaying the essential elements of the comparison process.
- ◊ Discuss discrepancies. Is the model a correct description of the properties of the real object? Up to what limitations?
- ◊ Put all data in a file, including measurement errors. Discuss the results, give conclusions.

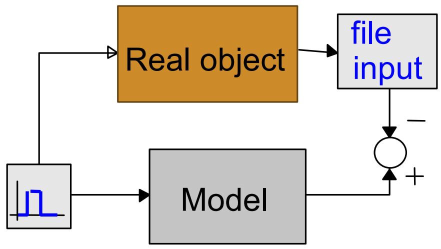

Figure 2. Comparison of measurements and simulations.

At the start of the project, during a plenary session in a lecture room, general information is given on the project goals, the rules and disciplines and the assisting staff. They are informed about the team composition and the type of transducer as the starting device (which differs from team to team). Next the students move to a laboratory room with all kind of facilities, including PC's, printers, measurement equipment, electronic and mechanical components and various construction tools. All kind of software is available (word processing, simulation software [3], virtual instrument tools). They may use the facilities of a special mechanical workshop too, after a short introduction on safety and responsibilities. A small budget is available for each design team, to buy components that are not in the Laboratory components store.

3 EXPERIENCES

At the introduction of this project a few years ago the student teams had more freedom in choosing a mechatronic system. They had no starting object (transducer) to be characterised, and they could start immediately with a brainstorm session on the mechatronic system to be created. However, it soon appeared that the student's creativity and imagination was in a too strong competition with one of the project goals: following a strict design trajectory. The students could hardly wait with the materialisation of their creative idea's and skipped most of the modelling and simulation phases. Another problem soon became manifest: the theory from the courses was often inadequate to be able to properly model and simulate the genius constructions they had in mind. This is the main reason that the teams are forced to used a start object which should first be characterised. Since that time, the designs were better prepared and the results improved.

Another stimulating element was obtained by increasing the competitiveness. The team with the "best" design is elected as winner. The video of the final demonstration is put on the web page of the project.

4 CONCLUSION

One of the project goals, the integrated application of knowledge from various lectures, is met: the students have discovered the multidisciplinary character of a mechatronic design and are aware of the practical value of many elements from the lectures.

Another important project goal: learning to follow a strict design cycle from idea through modelling and simulation to construction and testing, is only partly achieved. Students have to be more or less forced to first model and simulate a design, to study the feasibility and to discover practical limitations. Only after the introduction of the starting device and the explicit task to characterise this device the compulsory design track was followed. However, students remain reluctant to perform these steps first, and are still not fully convinced of the need for such preliminary studies.

A project like the one described in this paper contributes unquestionably to the motivation of the students. At the start, all teams show uncertainty and doubt about the track they have to follow, but within half a day most teams have well picked up the task and their enthusiasm grows with time, as well as their dedication. Only a few students need special attention, but most of the time the weaker students are supported and motivated by the stronger team members. There is a natural task allocation based on personal skills and interests, whereas also a process of self-correction in case of problems is noticed.

The project contributes significantly to the motivation of their study in general and the various theoretical courses in particular.

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