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MECHATRONICS

Mechatronics “a graduate perspective”

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Abstract

Over recent decades the development of a new engineering philosophy has occurred within the industry, that has become known as Mechatronics. The demand initiated by industry for engineers with such a different approach to the subject eventually guided universities towards creating dedicated degree programs for Mechatronics. The question remained how to teach such a different philosophy within traditional engineering departments. A new approach towards teaching Mechatronics pioneered at the University of Hull, with the emphasis on developing a project base supported by traditional teaching is described. This radical approach aims to dispense with the concept of passive theoretical learning and encourages an attitude of active education. © 2002 Published by Elsevier Science Ltd.

1. Introduction

With the development of even more sophisticated technologies there has been an increasing need for a new approach to engineering. As a result there is strong evidence to suggest mechatronics to become one of the most influential engineering disciplines within the industry. As with most new subjects, pre-trained Mechatronics engineers did not exist; engineers with traditional engineering backgrounds adapted along with the development of mechatronics to form the core of its industry. Although this development occurred over a long period of time the academic world remained oblivious or sceptical until recently. The question remained how to teach such a different philosophy within traditional engineering departments. A radically different approach towards the

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education of mechatronics was initiated at Hull University. This approach placed the main emphasis on project base practical engineering supported by traditional theory.

This paper aims to show the effectiveness of teaching Mechatronics within this framework. The analysis is based on the experience of two graduates who received Masters degrees in Mechatronics at Hull University. The advantages and disadvantages of a project based teaching technique from an early stage are highlighted. Also how these experiences influenced traditional aspects of the degree program. It will be shown how the links to existing engineering departments hindered or assisted the success of mechatronics education.

2. The need for Mechatronics

Increasing consumer demand for innovative new products has created a fiercely competitive marketplace and with shorter product life cycles and improved manufacturing facilities, the development of engineered products has occurred at an alarming rate.

Advances in computer, electronics and mechanical technologies have enabled products to be designed with increasing degrees of sophistication, complexity and flexibility. As a result the mechanical, electronic and computer control systems within a device have become more integrated and mutually dependent. Consequently the application of traditional approaches to engineering is becoming limited and the need for multidisciplined engineers is becoming more apparent. The efficiency and flexibility in the approach to business means that the considerable overheads carried by traditional companies are becoming unacceptable and uneconomic. The rigid structure and compartmentalisation of yesterday's business can no longer keep up with the demands and pace of today's market place – what is needed is a flexible approach to product design and problem solving, capable of rapid change in response to the market and efficient use of its resources.

In order to survive in this environment, it is becoming necessary to approach the changing state of business with a modified attitude towards engineering. In response to these demands, a new engineering philosophy evolved within the industry, which has adopted the name Mechatronics.

The new challenges presented the need for new thinking, but as with most new disciplines pre-trained Mechatronic engineers did not exist; engineers with traditional backgrounds simply had to adapt. Having identified the need for Mechatronics engineers, industry needed academic institutions to fulfil some of the training. Although this development occurred over a long period of time, the academic world remained oblivious or sceptical until recently. The demand initiated by industry for engineers with such a different approach to the subject eventually guided universities towards creating dedicated degree programs for Mechatronics engineers.

3. Teaching Mechatronics

Having established the need for teaching mechatronics, a number of universities attempted to integrate it into their engineering schools. Introducing such a diverse subject, which crosses traditional departmental boundaries, into a traditional engineering department raises some fundamental issues. Firstly, exactly who should have ownership of the course or can a new department be created? Secondly, with such a wide range of engineering subjects, what should be taught and at what stage is most beneficial? Finally, the question remained how to teach such a different philosophy with such a wide range of diverse subjects.

3.1. Which school does it belong to?

Unlike most engineering subjects, Mechatronics is not instinctively owned by mechanical engineering, electronic engineering or computer science departments. Also the creation of a new department may not be justified due to the unpredictable nature of student intake on a new course. Therefore, mechatronics degrees tend to be attached to an existing department usually electronic or mechanical engineering. In doing this, the courses tend to be dominated by the subject of the respective department – an inevitable outcome of basing the lecture courses around an established engineering discipline. The parent department becomes one of the most significant factors governing the subject matter taught and teaching methods used. This dominating effect may drastically restrict the development of different teaching methods and subjects hindering the growth of the new methodology.

At Hull University, the same problem existed that the new course would initially have insufficient student intake to warrant a department of its own, however, it was recognised that a radically re-structured syllabus was necessary for real progress. The course was based in the electronic engineering department with its main support staff taken from both electronic and mechanical engineering. In order to allow the new philosophy to develop within a traditional environment, the need to create a new approach towards teaching techniques was recognised.

3.2. What should be taught?

Defining the subject matter within a mechatronics course is not as obvious as more traditional disciplines. The nature of Mechatronic systems demands an awareness and understanding of a large variety of engineering topics throughout electronics, mechanics and computing. However, in order to fulfil the requirements of a degree program it is necessary to cover the required academic material in sufficient detail. This gives rise to a conflict between students gaining a broad understanding of a large subject area and the need to provide a highly detailed knowledge of a specific subject.

The diversity of subjects available makes it impossible to provide a comprehensive low-level program covering all of the material. This necessitates tactical selection of

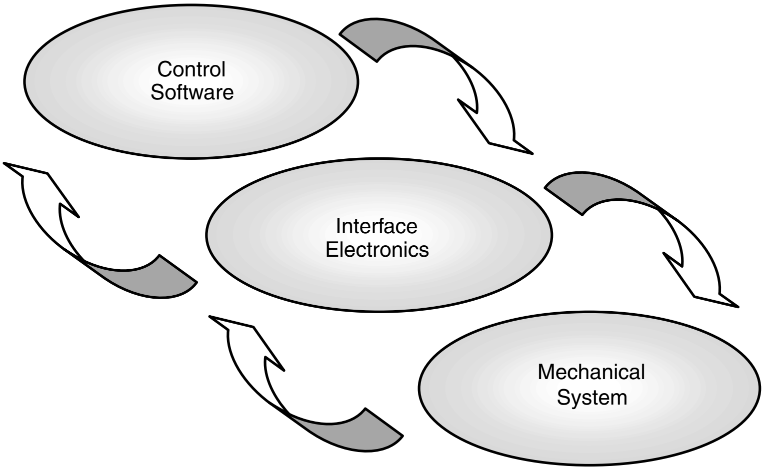

Fig. 1. Course content.

subjects to be concentrated on, covered loosely or eliminated. To this end it is essential to determine the spinal element of the course.

A mechatronic system by definition typically consists of an electronic system driving mechanics with a software based control system providing the functionality and facilitating the necessary flexibility (see Fig. 2).

The development of a mechatronic system can consequently result in a number of different electronic and mechanical systems incorporating a variety of technologies depending on its requirements. In order to enable the engineer to utilise the available technologies it is essential that control be understood.

The mechatronics course at Hull University used control as its spinal subject with modules covering a range of electronic, mechanical and computing topics forming the majority of the course. Departments such as physics and business provided additional non-engineering subjects.

3.3. How do we teach?

Having established the need for such a radically different methodology it was essential to create an environment conducive to the advancement of the new philosophy. The elimination of the possibility of creating a new department dedicated to mechatronics and the need for teaching traditional topics within the framework necessitates investigations into teaching techniques and methods.

Most universities took a conventional approach basing the programs around the existing lecture course system with the addition of specific mechatronic modules. Lectures provide the main source of knowledge supported with structured laboratories offering practical experience where applicable.

In order to allow the new philosophy to develop at Hull University, an attempt to create an alternative approach to teaching was made. The tactic taken was led

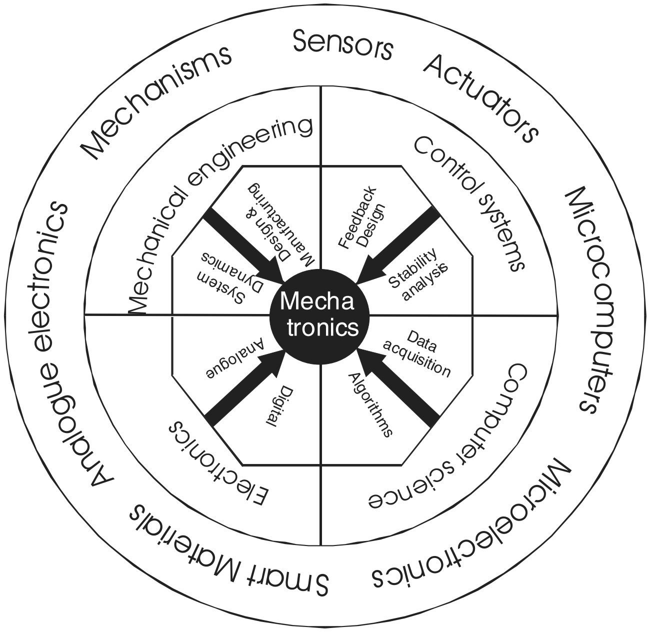

Fig. 2. Mechatronic system.

by the requirements of mechatronic engineers within the industry. In contrast to teaching the students by lecturing with limited structured laboratory work until the final years, at Hull the main emphasis was placed on project based education supported by lecture programs from the first year. The main aim of the project-based teaching is to build a situation for active learning of multiple disciplines. Placing students in direct contact with real engineering challenges creates a non-subject specific teaching tool. While vital subjects are taught via lecture courses, associated laboratory subjects that have not been covered are still studied within the project framework.

The practical aspect of the Mechatronic course differs from traditional laboratory exercises in that the objective is to design (and justify) a solution to a large-scale problem, rather than follow several training exercises in a pre-determined series.

The course is designed to provoke reaction, thought and innovation in order to find the best solution to any given problem. Traditional laboratory exercises tend to provide a clear set of objectives and sequence to achieve them. The projects encountered on the Mechatronics course contained a number of different possible problems and undefined objectives with no clear best approach. In most cases the initial task was to determine the specific nature of the tasks and define the objectives of the work. Similarly the method of completing the tasks is left to the student to identify, with some guidance from the support staff. By following this procedure the students are taught to use their initiative when faced with an unknown problem. Introducing this concept from the start of the course enables the students to adapt quickly, therefore allowing practical engineering to teach engineering thinking for the duration of the course. Having defined their own goals and deadlines (within a given period of time) the awareness of completion times and deliverables encouraged a more dedicated work ethic.

In order to support the project work theoretical studies provide the basic building blocks without being directed at a specific project. This provides the necessary knowledge to apply to problem solving activities. During the practical work many stumbling blocks are encountered, many of these are highlighted and indirectly explained by the theoretical studies. Consequently a greater understanding is achieved via associated learning.

Evidence of this was observed during practical exercises common to both mechatronics and electronic engineering. There was a tendency for mechatronics students to question the laboratory sheets in order to determine their accuracy. The electronics engineers displayed a more tasks focused approach where the mechatronics students tried to consider the whole system. This often resulted in mechatronics students considering solutions that have previously been unexplored in the attempt to create a better solution.

4. Course structure

The mechatronics program is a four-year masters degree with a three-year bachelor option. Throughout the program, the emphasis is on the project work and supporting lectures. In year three, a higher priority is placed on theoretical study in order to enhance the academic knowledge and support the engineering thinking gained. Introducing a higher theory content at this stage has enabled the students to examine and determine the areas they wish to specialise in. The program has been designed in a way that a large proportion of the knowledge and skills required by an engineer are provided by the practical work. By providing the theory with varying levels of detail within a framework of "just in time" lectures, enables the students to fully capitalise on the knowledge. The requirements of the course can be seen in Fig. 1.

The first year is based around two major projects encompassing the design, planning and manufacture of walking robots. In the first semester individual students' design and build walking robots capable of performing a given task, restricted by specific design criteria, budgets and time-scales. In the second semester computer controlled robots capable of performing a more complex task are created by groups of three students. The project specification imposes no limitations on the designs other than material and cost. Assessment takes the form of a series of reports and presentations. In order to provide theoretical understanding of engineering, lectures concentrate on providing a firm foundation of engineering principles. This incorporates mathematics, analogue and digital electronics, statics and dynamics of mechatronic systems and computer programming.

In the second year the emphasis is shifted onto industrially sponsored projects where the student works with an external company in order to solve an industrial problem. The involvement from industry enables the students to gain some experience of how real engineering operates and work on actual industrial problems with a realistic budget. The project structure was designed to incorporate supporting theoretical knowledge, develop practical engineering expertise alongside other skills required by engineers, such as project management, time management, control of budgets and communication. The projects were assessed by a combination of written reports and verbal presentations at a number of different stages, emphasising the need for management and planning. The supporting lectures develop the fundamental theories from the previous year and provide more specialised topics. Supporting lectures covered mathematics, mechatronics, servomechanisms, analogue and digital electronics, control, mechanical systems, processor architecture, computer programming, environmental engineering, optical electronics and business finance. In addition a hardware/interface project was undertaken.

The third year is largely based on a high lecture content in addition to smaller laboratory projects. Laboratory experiments specific to individual lecture courses and an interface/electronic hardware design and build project provided a large proportion of the practical work. At this stage a diverse range of engineering disciplines has been covered at a theoretical level whilst simultaneously gaining a reasonable understanding of practical engineering. The range of options available enables the student to follow a number of specialised routes. Unlike traditional disciplines the mechatronic students had the option to specialise in more than one area. Subjects as diverse as engineering materials, optical electronics and control could be pursued simultaneously. Although the level of specialisation is slightly lower than that of mechanical and electronic courses the flexibility of the system enabled students to tailor the program to their needs and interests. Subjects taught at this stage involve mathematics, robotic systems, image processing, control, processor architecture, CAD/CAM, materials technology, computer programming, environmental engineering, optical electronics, manufacturing principles and business management.

The fourth year further develops the lecture-based study into specialised subject areas within both electronic and mechanical engineering. In addition to the lecture courses, all students undertake a major final year project. At this stage lecture courses cover advanced control techniques, optical electronics, advanced engineering materials, surface engineering, design for manufacture/assembly, robotic systems and vision systems.

During the first two years individuals and groups of students work on a range of different projects covering a varied range of technologies. Within this framework it is not possible to formally educate each student in all the technologies available. However, within the environment created, a dynamic working culture evolved due to the interaction between students providing exposure to each other's work and a team-based problem solving mind set. This radical method of approaching a problem with insufficient theoretical background dispenses with the concept of passive theoretical learning and encourages an attitude of active education in order to solve a problem. Within a carefully devised project it is not only possible to cover the key areas of practical design, but also to create an environment where the most effective engineering solution can be reached without bias from any given engineering discipline.

In order to support project-based activities, a series of specific modules (Mechatronics Technology) ran throughout the first two years. This provided the opportunity to guide and support the activities. In addition to technical issues, areas such as report writing, presentations and relevant software tools were covered.

Existing departments in the university provided the remaining lecture courses. Electronic and mechanical engineering supplied the majority of teaching resources with non-engineering subjects provided by departments such as computer science, business and physics.

5. Discussion and conclusions

As expected of such a new and different subject, the Mechatronics course at Hull University tended to have relatively small intake when compared with the traditional courses. This resulted in a higher level of dependency on the electronic and mechanical engineering departments to provide supporting lectures rather than creating dedicated tailor made modules. Although based in the electronic engineering department, Mechatronics is very much treated as a separate entity responsible for itself. This proved to both hinder and aid the running of the course. Administrative and organisational aspects of the program occasionally became complicated and obstructive due to the multidisciplinary nature of the mechatronics study program. However, the willingness of staff members to adapt aspects of modules removed any associated problems. By treating mechatronics as a separate entity, it was possible to allow the new philosophy and methodology to evolve at it own pace.

By working on real projects with support from teaching staff, as opposed to tackling hypothetical problems, the students are able to see the effects of their actions and develop much greater self-reliance and independence. Working towards solving problems makes it necessary to seek the theoretical answers by means of research and then apply them to a physical example. When applying theoretical solutions to practical problems the purpose of the theoretical work is highlighted and a greater understanding is achieved. Having made decisions on design and problem solving, the true impact of the decisions is shown in the success or failure. The experience, whether successful or not, provides a greater understanding of the engineering techniques, concepts used and their limitations. The projects provide a learning environment that cannot be replicated with structured laboratory experiments or in a lecture course.

The students studying Mechatronics tended to develop a different attitude towards engineering than those studying more traditional degrees. Their interest was more from an overall problem solving approach rather than focusing on specific areas of engineering such as mechanical design. The perspective was shifted to solving the overall problem rather than tackling components separately, promoting ability to design solutions, not just understand traditional disciplines. The idea to innovate rather than follow the established route is established at an early stage through structured around the concept of learning through attempting to solve an overall problem using any available means. This resulted in an obvious tendency for the Mechatronics students to possess a higher level of self-motivation and to constantly push the boundaries of the tasks presented to them rather than looking for the most obvious solution. In order to do this it was necessary to develop non-passive learning and research skills from an early stage.

The progressive project-based approach taken at Hull University guided students to develop a higher level of self-motivation and encouraged engineering thinking, rather than a response to being "spoon-fed" theoretical work. The practical application of theory highlights its effect immediately. In addition to academic knowledge, the project work provides a tool for teaching industrial skills such as planning, budgeting and time management while providing students with some indication of how industrial engineers operate. The flexibility of the modules provided allow the students to follow a route complementary to their needs and interests incorporating a wide range of specialised subjects.

The diversity and individuality of the subjects, covered both formally and informally, consequently lead to a larger workload and therefore demands a high level of dedication and self-motivation.

Having been through the course detailed students gain a global perspective of engineering systems. The ability to view a problem from an overall point of view rather than task or subject specific enables the engineer to remain flexible and adaptive within the industry or research work making the most of their skills.

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