Challenging Educational Platforms In Mechatronics: Learning Framework And Practice

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Abstract: In this paper the integrated didactic approach to Mechatronics Education in the Intelligent Systems Laboratory at the Technological Institute of Piraeus (TEI), Athens, is presented. The learning process incorporates conventional and non-conventional methods since the introduction of the Mechatronics Courses in the context of the Control Education curriculum of the Institute. The constant interest increase of the students demands that tutors and lecturers sustain their Mechatronics knowledge in a high level. Equipment and experimental mechatronics platform are replaced frequently and most recent versions are also presented in the article.

Key-words: mechatronics, mechatronics education, educational platform, ‘Mechatron’, mechatronics learning.

1 Introduction

The concept of Mechatronics derives from the integration of technologies introduced in products and manufacturing processes in the 70’s in the leading industrial economies like USA, Japan, UK, Germany, France, Sweden and others. Nowadays, new ideas and solutions in Mechatronics applications still originate mostly in the major industrial and research poles of America, Europe and Asia. Greece, Balkan countries and recently Middle East experience a rapid expansion of Mechatronics applications. Industrial investments introduce digital automation and related systems in order to improve the efficiency of industrial plants. Administrations introduce microprocessor-based office and document-handling equipment to boost service productivity. Investments in light industry, transport, agriculture, the environment and other sectors, incorporate a significant Mechatronics-relevant component.

Though Mechatronics is a young discipline, it attracted the interest of engineering education right from the beginning. The educational practice of Mechatronics has been fairly developed in a variety of contexts and forms. This, in turn, has led to the identification of several important issues relating to the Mechatronics curriculum and to the didactic benefits expected thereof. Earlier work, for instance, focused on the ‘integration’ aspect of Mechatronics. Practitioners of engineering education pointed out that this essential feature of the Mechatronics agenda was per se a key didactic objective for any engineering curriculum [1-3]. Furthering on this concept, numerous theoretical and field studies have corroborated the value of Mechatronics in the context of an interdisciplinary engineering curriculum. In the area of didactic methods, Mechatronics education was proven especially receptive for
the application of project-oriented and problem-based approaches [4-7]. This gives to mechatronics considerable appeal, as a general-purpose educational instrument for delivering generic skills and competences. The present work reports on the findings of Intelligent Systems Laboratory towards this direction and presents a successful and universal case study of low-cost experimental educational platform derived through this learning process.

2 Mechatronics @ TEI of Piraeus
Intelligent Systems Laboratory (ISL) is the responsible unit for the delivery of the Mechatronics modules within the control-engineering curriculum of the Technological Institute (TEI) of Piraeus. The Department delivers a degree in Automation Engineering after seven semesters of taught courses and one semester of industrial practice. Two Mechatronics courses were introduced in 1998, in the context of a programme to advance and modernize the curriculum. The courses were initially named ‘Mechatronics I’ and ‘Mechatronics II’ and were taught in the fifth and sixth semester, respectively. Following a review of the curriculum, these were replaced by two new courses (‘Mechatronics’ and ‘Mechatronics Applications’) and were shifted one semester upstream in the Department’s programme.

The team responsible for the delivery of the modules, developed an initial solution for the courses, adapted to the requirements of the Automation curriculum, on one hand, and in line with the methods used and reported internationally, on the other. This focus led the team to seek answers to a number of key issues. On the top of this list was the fact that several topics of a conventional Mechatronics programme were covered by other parts of the main education curriculum of the Department of Automation. This is particularly true for basic technological subjects like ‘Electronics’, ‘Electrical Circuits’, ‘Control Systems Design’, ‘Programming Microprocessors’ etc. covered in specialized courses. At the same time, it was realized that few existing control or technology courses developed the problem-solving abilities of students. Also, none of these courses introduced the aspect of the integration of different technologies in order to offer multiple benefits in integrated devices and systems.

3 Mechatronics learning methods
Over the last ten years, ISL developed a participatory style to the way Mechatronics is taught and explored the project based learning method through the development of several cost-effective educational platforms. Students are encouraged to develop their own problem-solving approaches to any universal mechatronics project given to them. These approaches should be linked to and based upon the individual experience of each student. In this way, the Mechatronics modules are considered not only as conventional courses but also parts of a support environment for the individual development of students; the modules create the ‘boundary conditions’ required to keep the student’s own personal learning on track. Ten years of teaching practice shaped these general objectives into a concrete learning process, aspects of which are reported here. An essential goal of the Mechatronics courses is to foster the active and motivated participation of students. The interest of students was found to relate to a number of factors, including challenge, competition, group participation and more.

Six groups of two students each are practicing in the laboratory hall during two hours class under the supervision of two tutors. Classes take place two different days per week and tutors deliver mechatronics practice in ninety-six students in total every semester. The theoretical parts of the modules ‘Mechatronics’ and ‘Mechatronics Applications’ are taught every week for two hours each by the head of Intelligent Systems Laboratory.

The learning approach for Mechatronics Education is in line with four basic and strict principles.

- Communication Skills: The student through the assigned project should evolve and establish efficient communication routes to his colleagues and his supervisor.
- Experimental Study: The teams are encouraged to investigate and explore as much as possible potential solutions in order to achieve their goal.
- Praticipatory Learning: Through teamwork, cooperation and tutoring, group members are led to the optimal solution and gradually accumulate valuable experience on practical problems which will face on their future carrier as Engineers.
- Low-Cost Solution Delivery: Eventually, one of the key axes of this learning
approach. Cost efficiency is important for both student groups and the Laboratory. All assignments are implemented on low-cost mechatronics platforms developed and produced from the Intelligent Systems Laboratory itself. This minimizes the running costs of the Mechatronics Modules and permits the groups to get a mechatronics experimental unit even in their houses in order to work more efficiently.

The search for a structured way to represent these factors and their interplay led to the development of a theoretical model for the learning process of the student. The model comprises four stages as shown in Fig.2.

- **Challenge.** The student is presented with a problem statement that includes a complex (though not necessarily practical) goal. The goal ‘feels’ generally feasible but the way to achieve it not straightforward.
- **Explore.** The student develops an individual approach to resolving the problem, including breaking down the problem in manageable parts and deciding which parts of the solution are ‘outsourced’ and to whom.
- **Exchange.** The student exchanges views and solutions with others: fellow students, peers, teaching staff. Also, the student manages the distribution of work with partners.
- **Generalize.** The student is led to solidify selected parts of the inputs he has absorbed into a small number of reusable, therefore general, pieces of learning.

During experimentation all students are provided with high technology equipment, tools and instruments in order to face any manufacturing and assembling difficulty. Their tasks during the academic semester is firstly learn and understand basic topics of mechatronics and afterwards design, assemble and programme a low-cost mechatronic platform. The laboratory provides all necessary components and experimentation takes place always under tutor and trainer supervision.

### 4 ‘Mechatron’ series

The educational model of Intelligent Systems Laboratory is designed as a series of assignments (problems) of increasing complexity. Any of these problems can be performed using the same basic equipment: a small-wheeled mechatronics platform, the ‘Mechatron’. When Mechatronics mini-course was introduced in the curriculum of the department of Automation the foremost and top-priority requirement was for low investment and operation expenses in combination to the flexibility and adaptation of the laboratory infrastructure to the multiple and rapidly changing needs of the Mechatronics Engineer. Initially, with respect to the cost of the platform parts, ‘Mechatron I’ was introduced. The design consisted totally by low technology and recycled materials. It had a modular multi-floor design consisting of salvaged hard-drive disks held together with four threaded rods, spacers and nuts. The floors where accommodating a microcontroller, motor drives, sensors and actuators. The platform has proved to be a valuable source of learning, both to the students and to the teaching staff at the Intelligent Systems Laboratory. It has offered some significant opportunities to evaluate the educational performance of various approaches, technologies, tools and methods, with minimal
financial exposure and technical risk. ‘Mechatron I’ gathered positive opinions from both students and tutors.

Over the last six years, an overall assessment and redesign of the platform was performed. The features and the philosophy of the first educational platform have been preserved to the new one, but flexibility and modularity has been enhanced. All the key findings of the first apparatus were embodied in an entirely new design. The current form of the device, depicted in Fig.3, named ‘Mechatron II’ maintained the character of a compact, low-cost smart device adjusted to the project based group oriented approach and Mechatronics – Embedded systems design that capture the interest of the students and engage them in participatory learning, see [8]. ‘Mechatron II’ inherits a number of features from ‘Mechatron I’, yet, it is a modular system punched to specifications. It is capable of embodying different forms and layouts, through a combination of parts. The main body of the platform, in its basic configuration, consists of seven 1,5mm aluminum plates. The plates are joined together with 3mm bolds and nuts, forming a robust frame, which hosts the DC gear motors, the motherboard and the experimental board (breadboard). Additional electromechanical and electronic parts can be easily embodied on the specially manufactured plate surfaces. Movement is achieved by the use of a pair of DC gear motors or in a more advanced form closed loop servomotors. The wheels are machined from polyethylene and host a rubber ring to prevent them from sliding. The third wheel is an omni directional caster wheel. The structure of the system is integrated by the motherboard which hosts a computer-on-a-chip control device in a common 24-pin stamp package, a circuit for voltage stabilization, a serial port for programming and debugging and finally an integrated motor driving circuit.

A series of different competition – game specifications have been developed within the last six years since the introduction of ‘Mechatron II’. Each semester students have to achieve a specific task in order to complete successfully the Mechatronics course. Sensors and actuators are devices designed and manufactured by the teams. A minor number of examples of these competitions are presented below:

Fig.3: ‘Mechatron II’, before the addition of sensors, actuators and interface circuitry.

5 The competitions
During Each semester (usually at the second or third session), students form teams of two members. The composition of teams remains constant during the semester. Students are encouraged to consider ways to select their team partners with the main objective to combine skills and knowledge. The final examination is organized as a game event, with teams competing against each other. A ‘Mechatron II’ platform is given to each team and it remains to the team till the end of the semester (Fig.4). The team has the opportunity to experiment with the platform by forming and designing the proposed solution for the competition.

Fig.4: ‘Mechatron II’ platform kits
1) Locate & Carry a Load: Mechatron has to locate, carry and unload in a pre-specified position a number of objects (identical) which are scattered in an arena, in the minimum time (Fig. 5). The arena is marked by a 20mm continuous black line. Each object is cylindrical with dimensions 35mmX25mm with mass 15gr. The unload site is marked by a beacon of infrared radiation (Fig.5 – point A).

![Fig.5: The locate & carry task arena.](image)

2) The Fire Brigade: Mechatron has to locate and distinguish a fire source (candle) located in an arena, in the minimum time. The arena (Fig. 6) is marked by a 20mm continuous black line. The candle has 60mm height and it is located in a black tape circle of 60mm diameter. The candle is at least 100mm away from the borders of the arena.

![Fig.6: The fire extinguish task.](image)

3) Pray & Hunter: One Mechatron (the hunter) has to locate and capture another (the pray) in the minimum time. The arena has dimensions 2x2m and it is marked by a 20mm continuous black line. The pray and the hunter are positioned in the opposite corners of the arena. The pray transmits switching sound pulses of 200ms duration and 1000KHz frequency, it pauses for 600ms and then transmits a 200ms pulse of 2500KHz. The pray is captured if the ring bumper which is attached around it is pressed by the hunter. Penalties are given to the teams if the hunting time exceeds a specific limit or if the robots leave the arena.

4) The Carriage: Mechatron has to push a carriage and deliver its load to a specific position within an arena marked by 20mm continuous black line. The carriage is a 100mm rod with to free moving wheels attached to Mechatron with a free rotating joint. The target position is a beacon transmitting ultrasound signal of pre-specified frequency.

![Fig.7: The carriage task](image)

After the end of the competition each team has to compile and deliver an extended report of their performance, which explains in detail all the subsystems of the robot, the task and its performance.

5 Conclusions

Within this work two key points concerning Mechatronics Education in Greece, and moreover the Department of Automation in the Technological Institute of Piraeus has been presented. On the one hand there is the adoption of novel and modern educational methods in a learning model adapted to the needs of the Greek economy. On the other hand there is the development of flexible, efficient and low-cost educational platforms used in the context of this learning model. These two driving cores enhance and interact shaping a dynamic and adaptive process. Especially for the development of educational platforms ‘Mechatron II’ has proven its applicability and appropriateness in the Mechatronics Modules. Based on rapid technology progress and always on student feedback the Intelligent Systems Laboratory will continue designing new platforms to meet all future needs of learning Mechatronics.
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