TEACHING MECHATRONICS ENGINEERING A CHALLENGE OF THE NEW CENTURY

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Abstract:
One of the branches of the Engineering that more influences on the construction of our modern world is certainly MECHATRONIC ENGINEERING. Many definitions of Mechatronic exist, but more or less all talks about the technological integration of the mechanics, the electronics and computer science. A Mechatronic Engineer is a professional able to develop and to manage mechatronic systems, contributing to the development of the country by means of improvement of the industries for the profit of productive standards of world-wide class. Nowadays numerous challenges for the education of Mechatronics exist, among them are the following:

- The design and the putting in practice of the control continue being something own of the dominion of the specialist in controls.
- The controls and the electronics still are seeing like "additions" to the processes or equipments.
- Very few engineers of the industrial practice realize any class of physical and/or mathematical modeling.
- The mathematics is a matter considered more like an obstacle than like a matter that extends the capacities of the engineer.
- Very few engineers have the suitable balance between the analysis and hardware; essential for the success in Mechatronics.

How to obtain the suitable balance between the knowledge of Mechanical and Electronic Engineering, Computation and Automatic control for the suitable formation of a Mechatronic Engineer who satisfies the increasing demands of the industrial development and the abilities that are required for this specialist. In the present work answers for these and other questions are offered.
Key words: *Engineering. Education. Mechatronics.*

Introduction

Facing the challenges of the so-called knowledge society means to expand and to raise the professional standards of citizens. The university must prepare a professional with abilities to meet the challenge of the contemporary age with appropriate scientific and technological knowledge, bearers of human values for optimal performance as a member of society, with a projection that combines personal skills but above all work and social ones. Engineering is an exciting profession for men and women who want to immerse themselves in the process of development and construction of our contemporary world. The engineers are engaged in the management of people, ideas, resources and materials in order to build and adapt things and services. It is a generalized approach that engineers of the future must have the following attributes:

- Strong background in mathematics and science
- Ability to identify and solve real world engineering problems
- Multidisciplinary systems approach to engineering problems
- Adequate balance between theory and practice
- Depth and Competition in a discipline
- Skills in oral and written communication
- Skills for teamwork, leadership, professionalism, ethical behavior
- Be a critical thinker and independent person
- Be creative, visionary, innovative
- Be aware of global and social issues
- Skills in project management, risk analysis, time management, assessment of the economy

One of these branches of engineering that is deeply committed to this construction of our modern world is undoubtedly the Mechatronic Engineering.

Definition of Mechatronics.

There are many definitions of Mechatronics, but nevertheless they all refer to the technological integration of mechanics, electronics and computers. Mechatronics was a concept developed by a Japanese firm of robots, in the early 80's. At first, it was defined only as the integration of mechanics and electronics on a machine or product, but over time became consolidated as a new specialty of engineering that incorporated other elements such as computer systems, developments in microelectronics, artificial intelligence, control theory and others related to computers with the latest technology. And so it began lecturing in this new specialty in the major universities of the world's most industrialized countries. Coined in 1969 by the Japanese company Yakasawa Electric Company [1] [2], the word Mechatronics has been defined in several ways. A common consensus is to describe Mechatronics as a discipline integrating the fields of mechanics, electronics and information technology aimed at providing better products, processes and systems. Mechatronics is not therefore a new branch of engineering, but a newly developed concept that emphasizes the need for integration and intensive interaction between different areas of engineering.

Based on the above, It can be referred to the definition of Mechatronics proposed by JA Rietdijk [3] "Mechatronics is the synergetic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and processes." Meanwhile Craig [4] defines Mechatronics as a Synergetic Integration of physical systems, electronic controls and computers through the design process from the very beginning of it. This leads to a very complex process of decision making. He adds: Integration is the key element and complexity has been transferred from the domain of mechanical systems to the domain of computers, software and electronics. It also notes that Mechatronics is an evolutionary design that requires horizontal integration among various disciplines of engineering and vertical integration between design and manufacturing. Craig affirms that Mechatronics is the best practice for engineering synthesis, responding to the needs of industry and human beings.

The "Mechatronics" means many things to many people, but when you push someone to a precise definition usually refers to a picture shown by Kevin Craig consisting of four overlapping circles: mechanical systems, electronic systems, systems control, and computers. In the center, where all overlap, their union forms the Mechatronics. Mechatronics is more than mechanics and electronics, Mechatronics is really related to the whole design process of any physical system, which integrates controls, electronics, and computers from the very beginning of the design process.

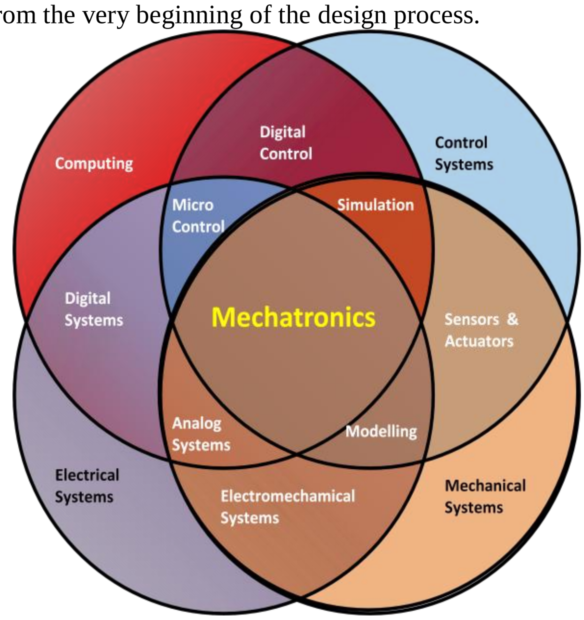


Figure 1. Definition of Mechatronics.

Mechatronic Systems

A typical mechatronic system picks up signals, processes them and as output generates forces and movements. The mechanical systems are then extended and integrated with sensors, microprocessors and controllers. The robots, digitally controlled machines, automated guided vehicles, electronic cameras, fax machines and photocopiers can be considered as mechatronic products. By applying a philosophy of integration into the design of products and systems are obtained important advantages such as flexibility, versatility, level of "intelligence" of products, safety and reliability and low power consumption. These advantages translate into a product with more user orientation and can be manufactured quickly at a reduced cost.

Mechatronic Product Classification

In the late 70's the Japanese Society for the Promotion of Machine Industry (JSPMI) classified mechatronic products into four classes.

Class I: mechanical products with primarily incorporated electronics to enhance or increase functionality, such as numerically controlled machine tools, variable speed drives, etc.

Class II: traditional mechanical systems upgraded with internal electronics incorporated therein, such as modern sewing machines.

Class III: Systems that retain the functionality of the traditional mechanical system, but the internal mechanisms are replaced by electronics. A classic example is the digital watch.

Class IV: Products designed with integrated mechanical and electronic technologies synergistically. Examples include photocopiers, washing machines and dryers, automatic cookers, etc.

Field of work of a Mechatronic Engineer.

Mechatronic Engineer is a professional capable of developing and managing mechatronic systems, contributing to the development of the country through improvement of industries to achieve world class manufacturing standards. In his professional performance must diagnose, design, build, maintain, manage, investigate and undertake possible solutions to needs that arise in society in their respective work and operation area. The formation of Mechatronic Engineering is aimed at developing personal and professional skills. Personal skills highlighted in the EIA Mechatronic Engineer are: Good communication in English as a second language, analytical capacities, creative development of new technological solutions, capable of teamwork, leadership in the management of interdisciplinary and multidisciplinary groups with a solid scientific and technical foundation, supported by the exact, economic, social and human sciences, which develops skills that ensure success in managing projects for the improvement and automation of equipment or processes, contributing to the socioeconomic development of industries country in a globalized environment.

The skills are evident in the following performance areas:

- **Industrial Automation:** To develop, integrate and give preventive and predictive maintenance to automated mechatronic solutions for the independent operation of processes, increasing productivity and improving product quality.

- **Flexible manufacturing systems:** To construct, investigate and manage solutions for advanced flexible cell production systems, including computer-aided design and manufacturing (CAD, CIM, CAM), by using discrete simulation, quality engineering, group technology and advanced manufacturing systems.
- **Robotics:** To integrate, innovate, and build computational intelligence algorithms, static or mobile robots able to carry out specific tasks simulating human functions, creating processes with improved quality, efficiency, accuracy, versatility, safety to improve the competitiveness of our companies.

Real Time Software

Another aspect that characterizes Mechatronics is the use of real-time software. The real-time software is at the heart of mechatronic systems. It differs from conventional software because its results must not only be numerically and logically correct, but must also be delivered in the right time.

- The real-time software must incorporate the concept of "duration", which is not part of conventional software. The software used in most control systems is also security software. The software malfunction can lead to serious injury and / or significant material damage.
- Asynchronous operations are uncommon in conventional software, but they are the heart and soul of real-time software.

The reason for the Mechatronics

The adoption by a company of Mechatronic application development and manufacture of products provides the company with a strategic and commercial advantage:

- The development of new and innovative products
- The enhancement and expansion of the potential of existing products
- Gaining access to new markets
- Or some combination of these factors

The How of Mechatronics

Achieving a successful mechatronic design environment essentially depends on the design team's ability to innovate, communicate, collaborate, and integrate.

- In fact, a mechatronic engineer's role is often to act to bridge communication gaps that may exist between specialized colleagues to ensure that the objectives of the collaboration and integration are achieved.
- This is important during the design phases of product development and particularly as regards the definition of requirements, where errors in the interpretation of customer requirements can lead to significant increases in cost.

Mechatronic Strategies:

- To assist and enable the development of new products and markets
- Expand and improve existing products
- Responding to the introduction of new lines of products from a competitor

Challenges of Mechatronic System Design:

- Mastering the future development in the complexity of the systems (Excellence in Innovation).
- Emerging of new products with distinctive functionality, better quality and / or lower cost (operational excellence).
- Effective and highly efficient processes for product design, manufacturing, and calibration.

Is new Mechatronics?

Mechatronics is simply the application of the latest technologies cost - impact on the areas of computers, electronics, controls, and physical systems to the design process to create more adaptable and functional products. It is precisely the practice of "Good Design" Many designers and engineers with a futurist thinking have been doing this for years.

Mechatronics requires horizontal integration between various disciplines as well as vertical integration between design and manufacturing.

Evolution of Mechatronics teaching: multidisciplinary - interdisciplinary – thematic teaching.

At the beginning of mechatronic studies modules or subjects were taught (first phase), then they went to an intermediate state where they begun to interact with the modules (intermediate phase) with a change of curricula, to try in the future go to a conjunction such that merely talk about Mechatronic modules and not electronic modules with mechanical control, etc. (last phase), in this case they must have a change in the organization.

Figure 2 shows in a simplified way the evolution of methods of study of Mechatronics from its beginnings to the potential state they should be, the colors of the circles match with the subjects represented in Figure 1.

First phase or multidisciplinary stage: During the last decade, the Mechatronic developed courses were originated in the Departments of Electronics or Mechanics of classical universities, using courses that were already trained and with a heavy mechanical content [5], so they were basically formed by mechanical subjects taught within the mechanical department and allowed students performing complementary subjects from the departments of electronics, computing and control.

In traditional Mechatronics, the focuses of the subjects or themes are normally developed by subsystem with multiple fields (primarily electronic, mechanical, control and computing). The interaction among disciplines is limited simply to the interfaces and rarely requires the development of a certain technology as a result of real integration with other technologies [6].

Intermediate phase or interdisciplinary stage: During the integration of HEIs in the Bologna process, new forms and methods of study appear, for example from having a purely formal lectures usually based on independence between subjects to become project-based studies or problems. When working with projects or problem arises the need to interact with other subjects quite different. Mechatronics, forces the real interaction between subjects / modules of different departments or areas. It appears the concept that students can create, program and operate a mechatronic product and that it is composed of mechanical and electrical elements, and must have a system based on a microcontroller for example and this element must be programmed properly to control his performance. In this phase we can find from the development of some subjects / modules carry out by two or more areas or departments (depending on year after year on the willingness of teachers responsible for them) to the full development of a curriculum that takes into account that interdisciplinarity is an essential element for the proper conduct of the courses.With this in mind disappears the concept of the previous phase, to begin to think of Mechatronics as a whole. To reach this, a drastic change in curriculum and thinking of the institutions is needed. Now it is necessary to work hard on a project basis or problems with modules or courses shared by both staff of a department / area as another, being more difficult to organize at the institutional level but more satisfactory in terms of results.

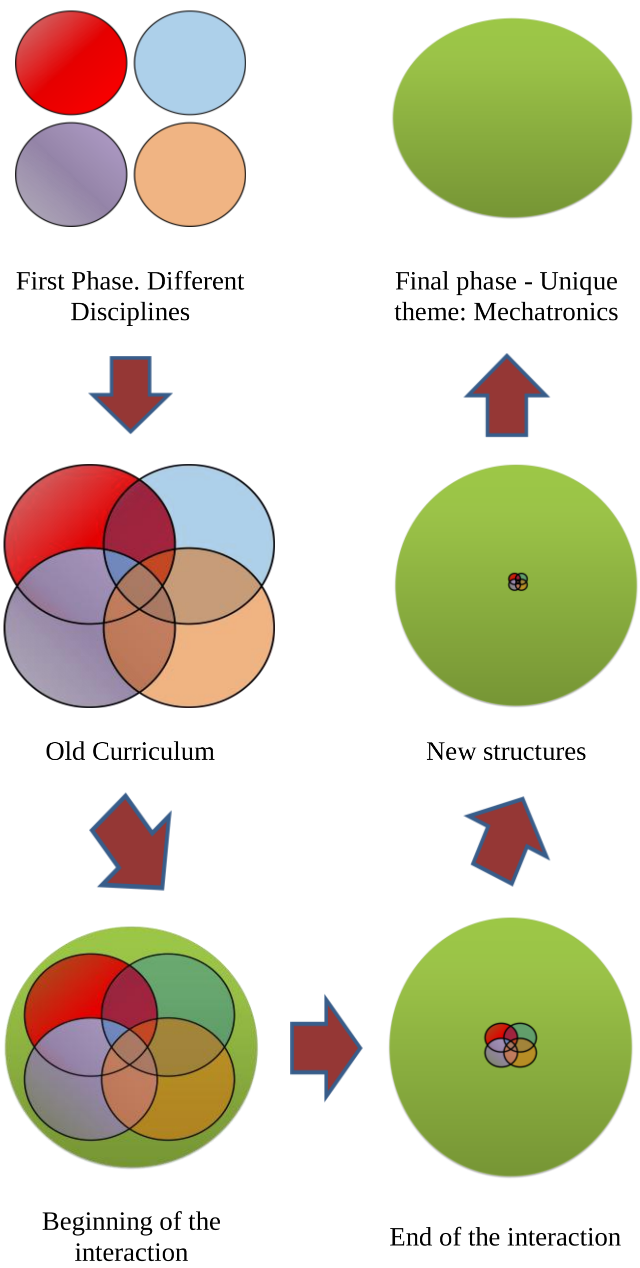


Figure 2. Evolution of Mechatronics as an academic discipline

Final phase or thematic stage the last stage is the design and establishment of the Mechatronics with its own identity, different from the mechanics, electronics, control, and so on. It is the creation of a Department of Mechatronics, with its own staff and dynamism based on the teaching and research in the field of Mechatronics. It is impossible to obtain from one day to another a department of such engineers in Mechatronics; it is necessary to go through intermediate stages where the base of knowledge of the staff is multidisciplinary.

Who rules Mechatronics?

Mechatronics is everywhere around us, from the hard drives of computers and robots, to washing machines, coffee machines and medical equipment. The electronics that control mechanical systems explains much of the average cost of an automobile today, going from controlling key aspects such as stability and braking systems to the climate control and seat adjustments. Talking to anyone involved in Mechatronics for quite some time respond without hesitation that it is now impossible to make a mechanical system that has no electronics in it [7].

Who will play the leading role in developing mechatronic systems? Will be the Mechanical Engineers who design the moving parts? Will be the electrical engineers, whose chips and sensors are the heart of control?

Would Companies trust in software engineers, which give their character to mechatronic devices? Or will be engineers of some description even indefinitely? Who then owns the Mechatronics? The answer to these questions is vital to establish standards for teaching Mechatronics. Craig also believes that mechanical engineers should be the leaders of Mechatronics. "We are the wider discipline and build physical systems," says Craig. "What has changed is that we incorporate electronic systems and controls in everything we do, not as an appendix or something added, but as part of design."

Because electronics has become such an integral part of mechanical design, mechanical engineers have had to learn to talk about sensors, actuators, processors, and code in the same breath as structural strength and materials. "We need to know how to use the devices electrical engineers create in our systems," Craig said.

"Electrical and other engineers don't have that experience, and they don't crave that experience," he said. They also don't have time for it. According to Craig, electrical engineering programs are tightly focused and often specialized. "In some instances, electromagnetic and control engineering are not even required courses in their curriculum, and yet for us they are foundational," he said.

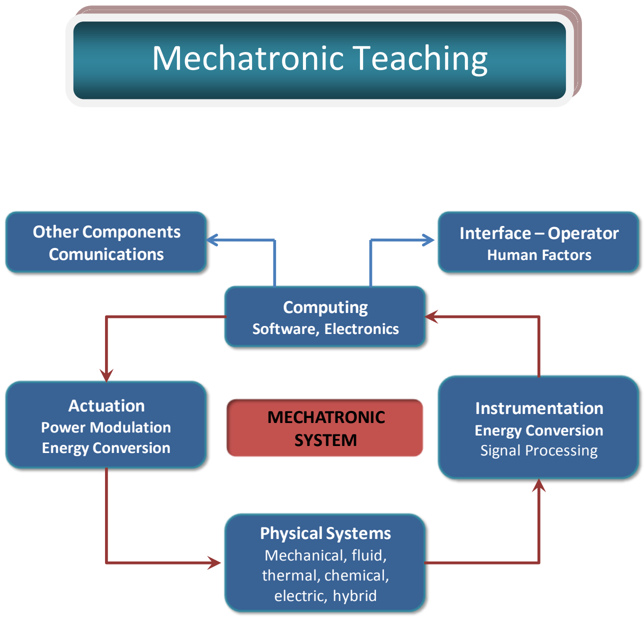
According to Craig [4], electrical engineering programs focus on narrow and stiff fields, and often specialize. Sometimes control engineering and electromagnetism are not required courses in their curricula, but for us are critical, Craig is a mechanical engineer, so it's no wonder that he thinks this way. Maybe one day Mechatronic Engineers replace Mechanical Engineers or all Mechanical Engineers will be Mechatronic Engineers.

Challenges to Mechatronic teaching:

- The design and implementation of control remains something of their own domain of control specialists.
- The controls and electronics are still seen as "additions" to the processes or equipment.
- Few engineers from industry practice any kind of physical and / or math modeling.
- Mathematics is a subject that looks more like an obstacle than a matter that extends the capabilities of the engineer.

- Only few engineers have the appropriate balance between analysis and hardware what it is essential to success in Mechatronics.

Components of Mechatronic Engineering Education.
The following chart shows in a graphical way the relationships between the different components of the teaching of Mechatronics Engineering:



Taking into account that there are different models, criteria and curricula to form a mechatronic engineer and besides there is a high demand in the post graduate program in this field, all this justifies and supports the work in this regard. Moreover, the articulation between undergraduate and postgraduate education and the interplay between these two concepts and levels of education suggests -both by the form as the content- to study, and to propose the establishment of a comprehensive training curriculum of a Mechatronic specialist which includes not only undergraduate education but also in the postgraduate training.
Both for industry and for universities these are key issues. There are specialists that sustain that in the XXI century all engineers need to become mechatronic engineers.
The industry needs engineers with their feet on the ground and a balance between theory and practice, a professional attitude, experience in multidisciplinary team work and exceptional communication skills. Universities need to know the answers to these questions to shape their curricula and better prepare engineering students for professional practice. This requires achieving a consistent teaching-learning process, which assumes a curriculum with an appropriate balance between theory and practice and between mechanics, electronics, computers and automatic control. In this regard, urges a strategy that explicitly reflects the development of practical – professional skills, responsive to current trends and concepts of mechatronic technology education with a systemic approach.
Given all the above definitions the following curriculum is designed to form a Mechatronics Engineer:

Curriculum Proposal for Mechatronic Engineering		
First Year		
Subjects	**Hours**	**Credits ECTS**
1. Linear Algebra	64	4
2. Physics I and II	160	10
3. Chemistry	64	1
4. Mathematics I and II	160	10
5. Descriptive Geometry	64	4
6. Mechatronic Drawing	80	5
7. Programming Principles	80	5
8. Introduction to Mechatronic	80	5
9. Fundamentals of Mechanical Engineering	80	5
10. Fundamentals of Electrical Engineering	80	5
11. Introduction to Maintenance	64	4
TOTAL	976	60
Second year		
1. Solid Mechanics I and II	160	40
2. Computer Aided Design (CAD)	80	5
3. Mathematics III and IV	160	10
4. Physics III and IV	128	5
5. Probability and Statistics	64	8
6. Numerical Methods	64	4
7. Electrical Systems and Technologies	64	4
8. Metrology	64	4
9. Manufacturing Processes	64	4
10. Electricity and Magnetism	64	4
11. Electronics	64	4
TOTAL	976	60
Third year		
1. Mechanics of Materials I and II	128	8
2. Materials Science	64	44
3. Theory of Mechanisms and Machines I and II	128	8
4. System Dynamics	64	4
5. Computer Aided Design of Electronic Circuits	64	4
6. Systems Modeling	64	4
7. Combinatorial Logic Systems	48	3

8. Analogical Control	64	4
9. Digital Control	64	4
10. Control of Quality	48	3
11. Hydraulic and Pneumatic Equipment	48	3
12. Process Automation	64	4
13. Stochastic Process	64	4
14. MATLAB Programming	64	4
TOTAL	976	60
Fourth Year		
1. Industrial Machine Design I and II	160	10
2. Robotics I and II	128	8
3. Sensors and actuators 64 4	64	4
4. Systems Interconnections	48	3
5. Computer Aided Engineering (CAE)	80	5
6. Artificial Intelligence	64	4
7. Automated Devices	64	4
8. Digital Image Processing	64	4
9. CNC Programming	80	5
10. Computer Aided Quality Control (CAQ)	48	3
11. Pattern Recognition	48	3
12. Control Systems 48 3 Real-Time	48	3
13. Vision Systems	48	3
TOTAL	944	60
Fifth year		
1. Mechatronic Ethics	64	4
2. Fuzzy Systems and Neural Networks	80	5
3. Flexible Manufacturing Systems	80	5
4. Computer-aided manufacturing (CAM)	80	5
5. Environment and cleaner production	48	3
6. Logistics	48	3
7. Mechatronic Project	500	33
TOTAL	900	60

Conclusions:

Many universities in the world and particularly in Latin America offer courses in Mechatronics, both undergraduate and postgraduate. In these curricula departmental barriers are broken, combining subjects and disciplines of various kinds. The formation of Mechatronic Engineering at the different universities is quite diverse; there are few precedents of a methodological and pedagogical study that what is really required to form a mechatronic engineer.

From the information gathered and analyzed curricula it can see that is a fairly general consensus that the common basis for a Mechatronic Engineering is the component of basic and basic-specific courses that shape the curriculum of a mechanical engineer, adding the necessary aspects of circuits, sensors and actuators, electronics, automatic control, etc. that are present in many electrical engineering curricula. However in the presented curriculum teaching concepts and methodologies has been used to establish the plan of subjects and disciplines needed.

The curriculum proposed in this paper meets those criteria and has also taken into account the needs and requests of the industry. It has some advantages over other revised curricula, such as from the 1st year are components of Computer Science, Mechanics and Electronics, which is maintained throughout the curriculum.

For Future works is important to analyze the joint between the undergraduate and postgraduate curriculum in Mechatronic Engineering and given the specificity of this subject see them as a single whole.

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