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MECHATRONICS EDUCATION – SYNERGISTIC INTEGRATION OF NEW PARADIGM FOR ENGINEERING EDUCATION

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Abstract. *The new economic order is demanding greater competitiveness of enterprises, which is only achieved with a higher level of automation of their processes. This means a greater demand in several areas of knowledge such as mechanical engineering, electro-electronics, control and computing systems, this is known as Mechatronics. Mechatronics engineering courses, as well as vocational training courses are rapidly increasing across the world. This paper defines mechatronics from a disciplinary identity towards thematic, and reviews some aspects of education training for mechatronics. To further illustrate this definition process, examples from various projects are presented. It proposes a list of features that a specialization program in mechatronics engineering should contain, increasing the need in the future for discipline based mechatronics engineers.*

Keywords*: Mechatronics education, Mechatronics Engineering Courses, Didactical Analysis.*

1. INTRODUCTION

The development of machines, automation and robotics projects, is a new economic trend that is reaching high levels of technology integration in production processes. This represents demand superior for control and automation systems, integrated with knowledge on mechanical engineering. The pool of knowledge in various areas such as mechanics, electronics, control systems and computing systems evolved the accelerated steps in the world creating the concept of Mechatronics (Figure 1). Mechatronics basically refers to mechanical electric systems and is centered on mechanics, electronics, computing and control, which integrated make possible the generation of simples, economical, reliable and versatile systems (Bishop, 2002). The name Mechatronics was coined by the Japanese to describe this combination of power electronics and microcontrollers in mechanical systems (Dunlop, 1997). Most engineers are surprised to learn that the term Mechatronics is nearly 40 years old. It was first used in 1969 by Tetsuro Mori and Koh Kikuchi at the Yaskawa Electric Corporation of Japan (Rooks, 1998, Lennon, 2008).

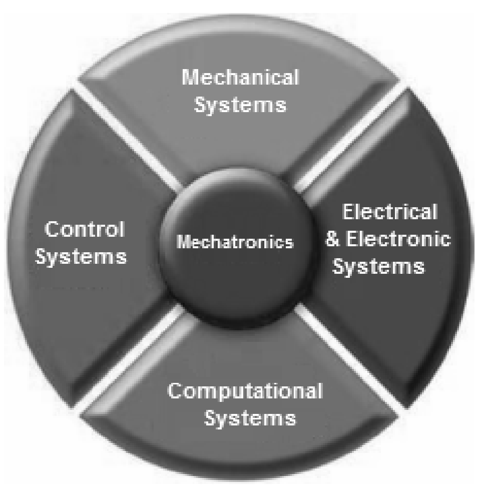

Figure 1. General idea of systems Mechatronics

Many important developments have occurred within countries, particularly over the past two decades. Some examples are rapid rates of economic evolution, social, political and technological change. In this era, it is allowed to see the interest of professionals in the industrial areas in acquiring new knowledge and adopt new concepts, especially in areas that are in evolution of microelectronics, robotics and programming techniques, which are imposed in the area of production, with equipment a more robust, that leads into account complete process, interconnections and creating interconnected networks that help in decision-making to managers of businesses.

Mechatronics design philosophies and concurrent practices for achieving the physical embodiment of those designs are seen as an appropriate response to the challenge. The adoption of such philosophies requires engineers with a new range of skills and attitudes, sometimes tagged as Renaissance Men, with a concomitant stimulus to the providers of training and education.

A paradigm is considered to be a pattern or example (Worthen *et al*., 2007). Also defined as a school of thought or philosophy. A paradigm is used to describe a constellation of world views held by individuals or groups that determine how they perceive and attempt to understand truth. Paradigms or world views are comprised of epistemological and ontological beliefs. “Epistemology is theory of knowledge or the study of nature of knowledge” as well as the limits and validity of associated with methods of inquiry. The practical application of epistemology is characterized by how individuals think knowledge or truth can be known. The limitations associate with ways of making inquiry into and presenting knowledge, and the inquirers’ perception of their relationship with the object of inquiry. Ontology involves the systematic study of being. In practical terms, individuals’ ontological beliefs determine how they think about reality and distinguish between what actually exists and what exists in thought. Understanding what a paradigm is and identifying what paradigmatic conception one ascribes to is crucial to comprehending the practical applications of various conceptions of curriculum for school practice. This information helps to clarify how individual’s paradigms influence their views of knowledge, methods of inquiry, and whether knowledge is verifiable or a belief that individuals hold.

In this paper, the theme on new paradigm for engineering education, exploring new directions for education reform and development, this paper develops a new paradigm of education, proposes new frameworks for technologies considerations and comprehensive analysis of engineering education. In the new paradigm, the future of the world is assumed to be in multiple globalizations including technological, economic, social, political, cultural, and learning globalizations. Also, these globalizations are rapidly evolution and interacting with the whole world. The new paradigm assumes that the education environment is inevitably characterized by synergistic integration, including globalization, localization, and individualization at different levels and in different aspects of the industrials system (Figure 2). Synergism and integration in design set a mechatronic system apart from a traditional, multidisciplinary system.

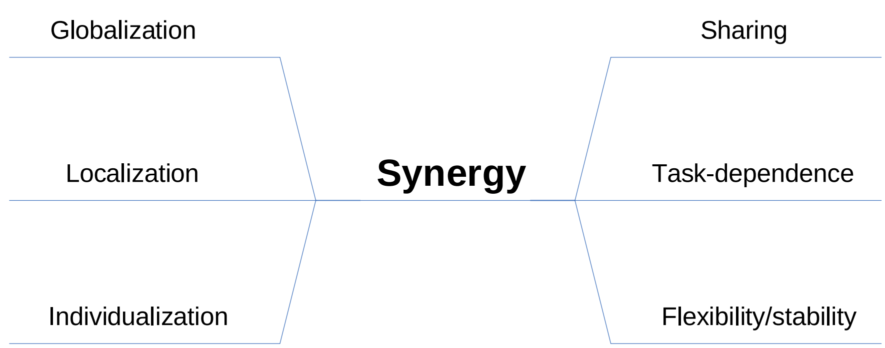

Figure 2. New Paradigm - Components of a Synergy

2. METODOLOGY

In mechatronics, balance is paramount. The essential methodology of a mechatronics engineer and the key to success in mechatronics is a balance between two sets of skills: (i) modeling (physical and mathematical), analysis (closed-form and numerical simulation), and control design (analog and digital) of dynamic physical systems; and (ii) experimental validation of models and analysis (for computer simulation without experimental verification is at best questionable, and at worst useless) and understanding the key issues in hardware implementation of designs.

Based on an example of mechatronic design (Lengerke *et al*., 2008); methodology project usually consists of following steps: (i) Specification system being designed, (ii) Division of the system to be designed into sub-systems, (iii) Generation of implementation variants of sub-systems, (iv) Modeling and simulation of implementation variants, (v) Choose the best variant, (vi) Construction of the prototype of the controller through a method of rapid prototyping system, (vii) Programming and debugging the program of control, (viii) Construction of prototype of the controller; e, (ix) Tests of the prototype. A mechatronic design must be able to simplify mechanics systems, have a lower cost of development and time if compared to other types of systems should be easy and flexible to incorporate modifications and new changes.

The linkage between them and the reality of the institution was broken. Sometimes they were expressions of hope about how students would develop. As shown in Figure 3, hope did not necessarily find an appropriate response in the curriculum. It is a language of broad terminology about motivation, interest, intelligence, critical thought, willingness to learn, and in engineering-analytical thought and problem solving. It is a mix of cognitive and affective. Some aims are more tangible from a measurement perspective than others. The role of objectives and outcomes is in the interpretation of aims into practice, and that practice involves the way that students teach (Heywood, 2005, Parasuraman and Ganapathy, 2002).

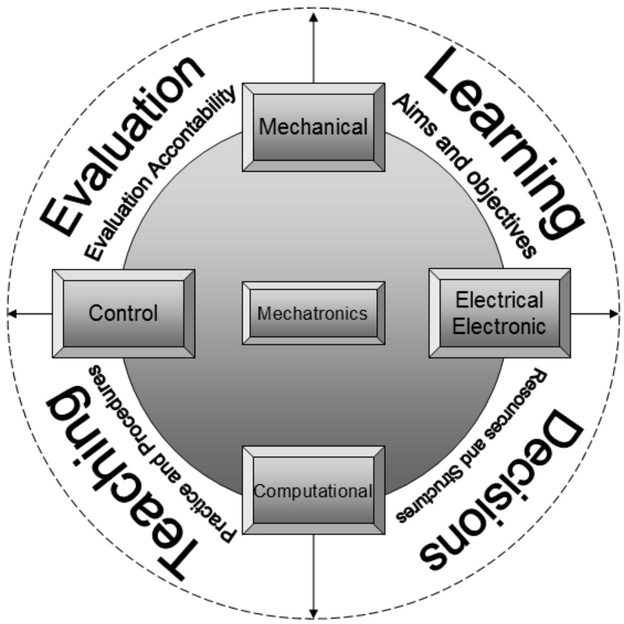

Figure 3. A model of the Mechatronics evaluation process within a sub system of specialization education

3. MECHATRONICS COURSE

The attraction of man by new together with the continuing need for development, crop up on the industries, such as the Mechatronics, system integrator modalities of science engineering, making the interactive and complementary.

Mechatronics always existed, but was not mentioned of this form. His nomination gave after the increasing demand of the industry by a professional more specialized and integrated in the various areas and systems that a project may involve. The main concern in the academic world, are responsible to educate these professionals required of labor market, was: how to teach Mechatronics? Limitation of traditional engineering becomes natural training contents for this training: systems (mechanical), interfaces (Electronics) and software (computational); points keys to the day by day of projects, industries and technological innovations.

Some disciplines of Mechatronics course are: safety at work, manufacturing processes, machines, electric/electronic circuits, automation, and programmable logic controller. It is possible to observe the variety of disciplines, but all these correlated, because they are common in some topics.

Many new Mechatronics programs and courses have been developed during the last decade. The most common pattern is that Mechatronics programs. Courses and departments have their origin in either mechanical engineering or electrical engineering, however, with the majority in mechanical engineering (Grimheden and Hanson, 2005). The most usual approach is to add courses in electrical engineering, computer science and control theory to the existing mechanical engineering curriculum, or for example to let electrical engineering students take courses in mechanical engineering and let them major in Mechatronics. This stage is defined as the multi-disciplinary stage. The objective of Mechatronics training is in addition to the dissemination of technological knowledge relating the engineering areas educates and enforces the new professional to be dynamic, active, diligent, and laborious (Figure 4). Must develop abilities that are required on the labor market: team work, motivation, innovation, management and control procedures and flexibility.

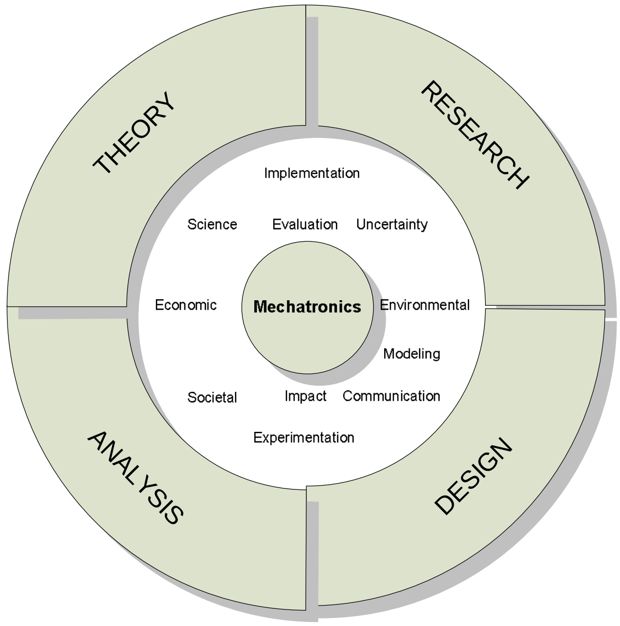

Figure 4. Roadmap for dissemination of mechatronics technological knowledge

For students who are interested in pursuing a specialization in mechatronics engineering, in Brazil some institutions offers a certificate of Mechatronics. The requirements are classes in the various topics of mechatronics: control theory, automatics systems, interfaces, sensors, actuators, mechatronics project, robotics, computer programming and industrials networks. Some of these courses are from other departments giving the student a multidisciplinary perspective of mechatronics. Students from mechanical engineering, electrical engineering, and computer science have received or are currently working towards the certificate. A mechatronics project is also required where the student must design, build, and demonstrate a mechatronic system (Figure 5).

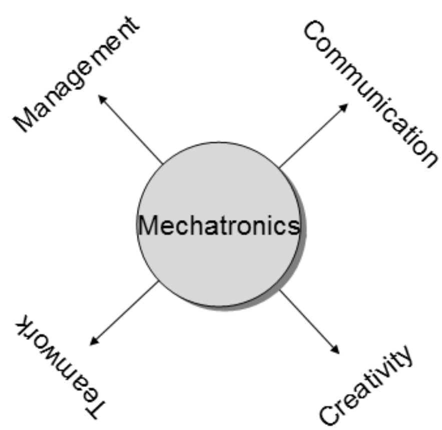

Figure 5. Perspectives for Mechatronics projects

The most commonly found courses in mechatronics are project based and have strong connections to laboratory exercises. The concept that the students will create, program and run a mechatronic product where the mechatronic product consists of mechanical parts, electrical parts and the ubiquitous microcontroller seems to be dominant. The students are primarily mechanical engineering students with basic knowledge in electrical engineering and computer science, and the faculty in many cases consists of a single faculty member or a handful of members with a special interest in expanding mechanical engineering into mechatronics (Craig, 2001).

3.1 Need for Mechatronic for engineering curriculum

Advances in computation, electrical and mechanical have allowed that products to be developed with a high degree of complexity and flexibility, and thus its constituent parts has become deeply integrated and dependent on each other.

Consequently the implementation of approaches traditional engineering has become limited and the need for a multidisciplinary engineering has become apparent within the industries.

Consequently, mechatronic has severely affected the basic nature of engineering education presents a model interdisciplinary academic and that balance the traditional engineering curriculum. Therefore, mechatronics – a multidisciplinary model – began to replace the traditional disciplines of a curriculum of teaching institutions all developed countries. The mechatronics is widely extended in the world in particular in developed countries with a broad acceptance by institutions and industries.

The modern view of curriculum is comprised of traditionalist and contemporary conceptions. An overview of the definitions that follow illustrates that curriculum has been variously defined as a content. Subject matter, a plan, experience, a system, and a field of study. The traditionalist's view of curriculum is grounded in the belief that curriculum content should be characterized by the inclusion of classical subjects and essential skills. The teacher's role is to help students learn permanent knowledge and think rationally. In essentialism, teachers guide students in mastering content based principles and facts and in becoming competent learners. Students are expected to be accepting of teachers' knowledge, never questioning their authority. Students' idiosyncratic interests are considered irrelevant to developing the curriculum.

The modernists advocate for a technocratic approach to curriculum making. In accord with their belief systems, curriculum was presumed to be comprised of identifiable components and procedures that are knowable and predetermined. The technocracy affiliated with the modern view of curriculum has been credited with promoting a sense of calmness by assuring that there are procedures to assure an orderly and efficient development and control of the curriculum (Hunkins and Hammill, 1994). Therefore, the qualified engineer to work in mechatronics area will be a perfect integrator that can extract the best of each science and technologies and offer knowledge for the construction of a final product.

4. MECHATRONICS PRODUCTS AND SYSTEMS

A typical mechatronic system picks up signals, processes them, and, as an output, generates forces and motions. Mechanical systems are extended and integrated with sensors, microprocessors and controllers (Acar and Parkin, 1996). The fact that such a system detects environmental or parametrical changes by sensors and, after suitably processing this information, reacts to them, makes it quite different from conventional machines and mechanical systems. For example, robots, digitally controlled engines, automated guided vehicles, electronic cameras and hard disk can be mentioned as typical mechatronics products.

For the development of a country are necessary processes of integration between the university and industry, science and technology. To achieve this goal is important to search for approximation of the university and industry, between the world where they generate knowledge and world production, according to the general objectives of the research around in order to be determinants of the social process, which to take the scientific production and the generation of new technologies in a projection for economic expansion and social development of a country.

The university and industry integration can be defined as a collection of activities, structures and concepts, involving the exchange of resources, ideas and influences between some units within the university with non-profit organization. Accordingly, the collaborations are not only in search engines under contractual to subsidize research and industrial development, but leads to formal or informal agreements, where they are outlined the general and specific objectives of research, inclusive the related aspects to commercialization of results.

Some robotics laboratories, work with companies through research on a methodology, performing and searching for a conceptual and theoretical framework, which serve as source for studies and proposed services, complemented by an extensive literature review found that works on the interaction University – Industry (U-I) has been an evolution trend, disappearing boundaries between areas of knowledge, where changes are happening profound way to produce science and incorporating knowledge in the production of goods and services. This has also led to the emergence of new areas of study in these laboratories have been capable to produce original vision of new horizons, where academic institutions have been identified as new sources of innovation for companies.

The activities of scientific and technological research for extension, consulting organization and specialized services of researches groups are specially focused on the development of scientific projects and industrial applications related to machines design, mechatronics, biomedical and industrial automation.

4.1. Mechatronics in Biomechanics, Medicine and Surgery

In this area, the researches are developments auxiliary systems for the clinical analysis and dynamic modeling of biological phenomena. The various fields of activity of the group stand out the motion walk, development of equipment for biomechanical analysis and design of medical robotic systems. Some research projects are:

- *Generation of human locomotion patterns by means of nonlinear oscillators*: The objective of this work is to present a system for generating patterns by means of coupled nonlinear oscillators, applying this system to a bipedal robot model. In this area is present some concepts about the human nervous system and its relation with the motor functions (Pina Filho *et al.*, 2008). In the analysis, is consider a 2D model, with the three most important determinants of gait (the compass gait, the knee flexion, and the plantar flexion of stance ankle), that performs movements parallel to the sagittal plane. Using nonlinear oscillators with integer relation of frequency, we determine the transient motion and the stable limit cycles of the coupled oscillators network, showing the behavior of the hip and knee angles. Modification of the step length and gait frequency can be obtained from change of few parameters in the oscillators.

- *Study and Design of equipment for low-cost analysis for the walk of amputees:* The integration of various disciplines in this project allowed the research of various subject areas, such as human anatomy and physiology, multibody systems dynamics, solids mechanics, instrumentation and signal processing. This work is conducted the study of the dynamic mobility of patients with transfemoral amputation and design of a system for forces and momentum dynamic analysis to be used in the analysis of handling of patients (Figure 6).

Figure 6. Transfemoral Prosthesis (Raptopoulos, 2003)

4.2. Mechatronics in Specials Machines Design

In this area, research and equipment and systems development in the areas of industrial automation systems, special machines design, robotics and tribology. Capability to design and produce specialized equipment with required hydraulic, pneumatic, electronic, and electrical systems. Produce specialized custom machines and assemblies for a large industrial base. The relationships between industries with university form an alliance in search of a technology to increase their productivity. At the time, the performance of machines equivalent to half obtained by internationals competitors (Figure 7).

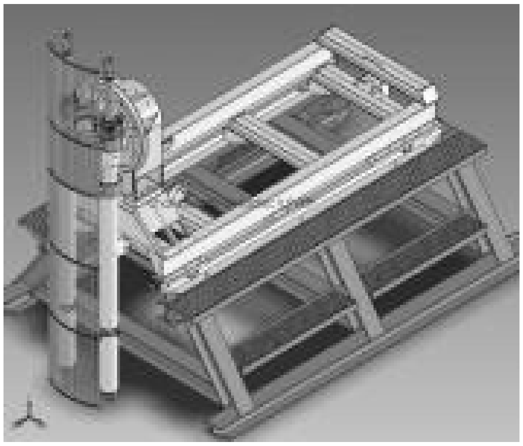

Figure 7. Design drilling of soil machine.

4.3. Mechatronics in Robotics and Manufacturing

Current research projects on intelligent mechanical systems include autonomous unmanned ground vehicles, automated guided vehicles, remotely operated vehicles, autonomous underwater vehicles, robotic excavation systems, pipeline inspection guided, automated pipe inspection systems, automated assembly systems, robotic rehabilitation systems, multi-fingered robotic hands, advanced mechanisms, manipulation, mobile robots, biomimetic systems, manufacturing design and integration of automated special machines and automation systems for production and manufacturing. Some of current and past research projects are:

- *Depth control of remotely operated underwater vehicles using an adaptive fuzzy sliding mode controller*: Due to the enormous technological improvements obtained in the last decades it is possible to use robotic vehicles for underwater exploration. These vehicles, often called ROV (Remotely Operated underwater Vehicle), have been substituting for divers in the accomplishment of tasks that may result in risks to human life. In this respect, ROVs have been used thoroughly in the research of subsea phenomena and in the assembly, inspection and repair of offshore structures (Figure 8). During the execution of a certain task with the robotic vehicle, the operator needs to monitor and control a number of parameters. If some of these parameters, as for instance the position and attitude of the vehicle, could be controlled automatically, the teleoperation of the ROV can be enormously facilitated. In this research, an adaptive fuzzy sliding mode controller is proposed to regulate the vertical displacement of remotely operated underwater vehicles. The adopted depth regulator is primarily based on the sliding mode control methodology, but a stable adaptive fuzzy inference system was embedded in the boundary layer to cope with the uncertainties and disturbances that can arise. Using Lyapunov stability theory and Barbalat's lemma, the stability and convergence properties of the closed-loop systems were analytically proved.

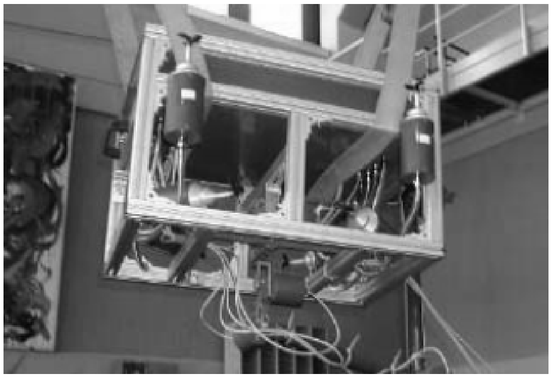

Figure 8. Underwater vehicle Prototype (Bessa *et al*., 2008)

4.4. Mechatronics in Industrial Issues

Its main area is to manage the industrial accident investigation activities of research laboratories. In order to effectively prevent workplace accidents, it is important to gather knowledge on the causes and mechanisms of as many types of workplace accidents as possible, through the on-site investigation of actual accidents. Some laboratories have a legal privilege to undertake investigations of accidents of mechatronics systems.

Upon request by the administration, laboratories dispatch researchers with relevant expertise to an accident location. These researchers carefully observe the workplace conditions, and bring back, if necessary, materials to the laboratory for further analysis or testing. Accident analysis reports are compiled as soon as possible and subsequently presented to the appropriate authorities for reference during administrative processes; such as the revision of regulations, guidelines, technical standards, and so on.

- *Structural accident of a ship unloader due to wind Forces*: Ship unloaders are large machines with the steel structure subjected to operational cyclic and impulsive loading. Besides the operational loading, the wind must be taken as a main loading for this type of structure, since it must be able not only to behave in safe condition, regarding its stability, stress levels and displacements, but also to remain parked over the pier during the occurrence of the worst wind conditions. For example, in these projects normally is presented the description of the accident caused by wind forces (Figure 9). In order to technically describe the occurrence, the wind forces were computed with the help of theoretical background as well as with experimental results raised from wind tunnel tests, taking into account the input of the recorded data of wind during the accident. At the same time the hydraulic brake system was analyzed and the resultant braking forces were compared with the total drag wind force over the ship unloader. The results of the wind structural analysis together with the mechanical braking system were taken to conclude on the main causes of the accident and to improve the decisions that must be taken by the port authorities to avoid this type accident in the future.

Figure 9. Structural Accident of a ship unloader and prototype (Batista *et al.*, 2005).

5. CONCLUSIONS

The important point of the concept and philosophy of Mechatronics is the concurrent combination of Mechanical, Electronic, Control and Computer, in an integrated mode to obtain in the product characteristics as flexibility and intelligence, and in design, systems mechanically simple, lower-cost and easy to changes. As the automation will become more present in the factories and industries, the demand for a professional mechatronics is growing, mainly in automotive industry. As the demand for the profession grows, the area of performance that engineer also grows, currently are the development projects of intelligent equipment, projects, automated production lines, the development and deployment of software for the industry and the control and maintenance equipment.

Modernization of production and processing continuous lines in industry requires well prepared graduates able to solve complex tasks in field of industrial mechatronic systems. Proper teaching support of courses utilizing modern learning methods contributes to satisfy these challenging goals.

In last years, research groups has constructed and consolidated a history on field of research and scientific development in the area of mechatronics projects, participating actively of the events and projects it deserves. The interests of groups is the radiator center of teaching and research, training human resources, promoting and preparing for consulting organizations in the country and abroad, developing research projects in cooperation with companies and institutions, creating partnership and alliances and characterization of the extensive spectrum of mechatronics activity.

As seen before, the increasing need for a multidisciplinary expertise, accretion the demand for engineers and specialists competent to integrate synergistically the positive aspects of each of the science and technologies (electrical/electronic, control, mechanical and computational) in order to achieve a final product. In this context resurge then the mechatronics - a multidisciplinary science - which allows the technicians and engineers have an overview of the process. The necessity for Mechatronics education has been application driven from the needs of industry, and it is competitive. Mechatronics may be regarded as a design philosophy, which incorporates a systems approach to the design of products and processes. The learning experience of students in the Mechatronics philosophy should essentially involve team-working activities with a large element of hands-on practical work.

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