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Title: Mechatronic design implemented in the development of virtual and physical prototypes

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Introduction

- The development of mechatronic and robotic systems is based on the research, design, construction and implementation of mechanical, electrical, electronic or control integration, with the aim of saving energy and optimizing costs, manipulating processes and systems, and increasing quality to obtain a final product.
- Applied research seeks the use of the knowledge acquired to systematize and implement the practice and then acquire a new knowledge and learning.
- There are methodologies aimed at specific objectives and to carry out various processes.

Introduction

Ullman 1994

The detection of the problem,
Conceptual design,
Product development and product support

Pahl G. et al, 2006

Conceptual design,
Construction,
The design for quality and to have the minimum of costs.

Ulrich y Eppinger, 2013

Book “Product design and development”.

Cross 2005

Design applied in engineering and products,
It is based on conceptual and physical design.
It features all 35 Jones Design Methods.

Tomiyama et al, 2009

Division of methodologies in concrete and abstract.

Gorrostieta et al., 2015

Synthesis of the methodology that summarizes the most commonly used activities by several authors to carry out the design and construction of a prototype.

Methodology

1. Identify the problem or need and define the engineering specifications that the product should have.
2. Concept generation.
3. Preliminary design.
4. Simulations with the use of a virtual prototype.
5. Determine mechanical and electromechanical components.
6. Determining electronic components.
7. Building the prototype.
8. Programming the control system.
9. Determine the level of interaction between user and robot.
10. Assessment between simulation and analytical results.
11. Validate the system or machine functionality.
12. Report the results.

Methodology

Design and construction of mechatronic prototypes

- It was implemented for the development and evaluation in the class Integrator Project and Research Seminar that is held in the 9th semester of Engineering in Mechatronics at the Technological University of the Mixteca.
- 36 prototypes were developed, which had as mandatory requirements to generate a physical prototype involving a mechanical, electronic, control and human-machine interface system, as well as the virtual prototype.
- A written paper was requested that included a schedule of activities, calculation memory and design plans, a poster that was used in a local exhibition, an operating manual and a maintenance manual.

Methodology

6 projects are presented. In the first case of study each of the 12 points mentioned above are developed and to simplify the presentation of the rest of the projects, the definition of the problem is shown indicating the problem, the overall objective, the description of the design and the presentation of results.

Three categories were proposed by students:

Rehabilitation robots,

Mobile robots and

Manipulators and various machines.

Results

Rehabilitation robotics

To develop robotic rehabilitation systems, it is necessary to consider end-user adaptability, energy consumption and technology acceptance by therapists and institutions specializing in rehabilitation (Acevedo Londoño et al., 2017).

Knee rehabilitator

The general objective is to present a functional tool at the mechanical-electrical-computer and control level to provide an alternative, for both doctors and patients, in such a way that diagnosis and rehabilitation are justified by graphs obtained from the efforts exerted by the working prototype.

Results

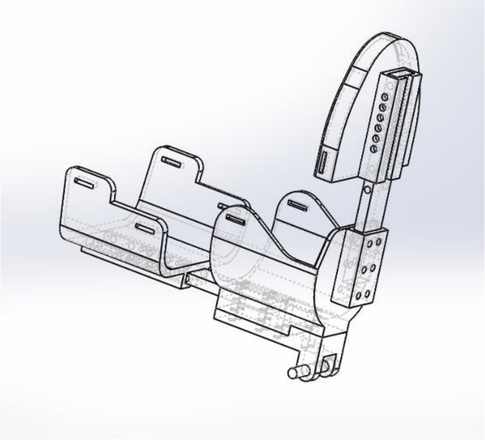

Figure 1 Preliminary boot design

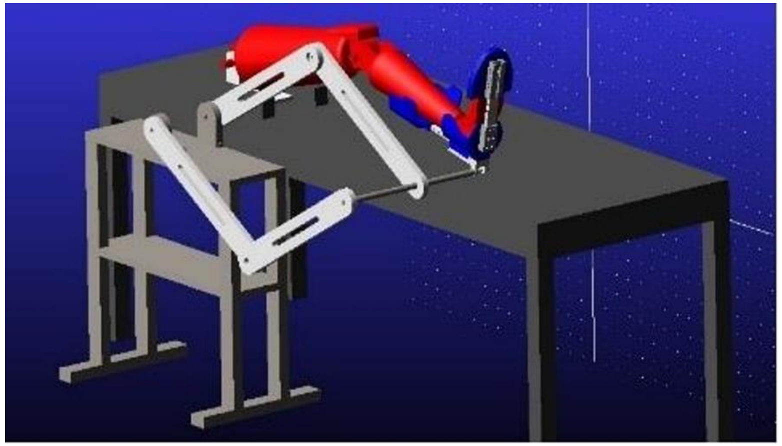

Figure 2 Simulations of a virtual prototype

Table 1 Computer programs for use of the virtual prototype

Software	Application
SOLIDWORKS®	Mechanical simulation to get engine torque, motion simulation and material resistance simulation.
ADAMS View™	Dynamic simulation of the mechanism
MatLab®	Diffuse control generation for engines
LabVIEW™	HMI interface so that the physical therapist can manipulate speeds and positions that are required for therapy
Proteus	Electronic simulation of power and control components

Reference Source: Own elaboration

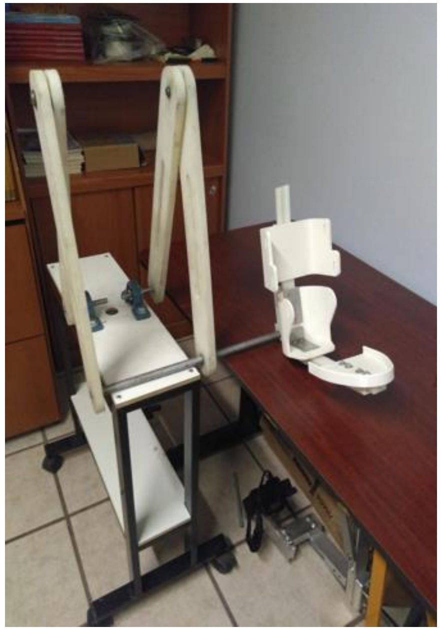

Figure 3 Final physical prototype

Results

Mobile robot: Hexapod

Problem:

Build the prototype of a robot for searching people after an earthquake, considering the use of a hexapod locomotion system that will allow displacement in rough and uneven terrain in less time compared to other locomotion systems.

Results:

- Operational tests were conducted through ADAMSView™ software, to demonstrate that robot movement is possible,
- The material used for the mechanical prototype was 3D printing, as well as metal sheet,
- 3 motors were used to handle each of the limbs, and an open loop control system for the first tests, which was subsequently changed to a PID control to manipulate the motors,
- To control the movements of the hexapod a basic interface was developed along with a Raspberry Pi card and the mini-master controller.

Results

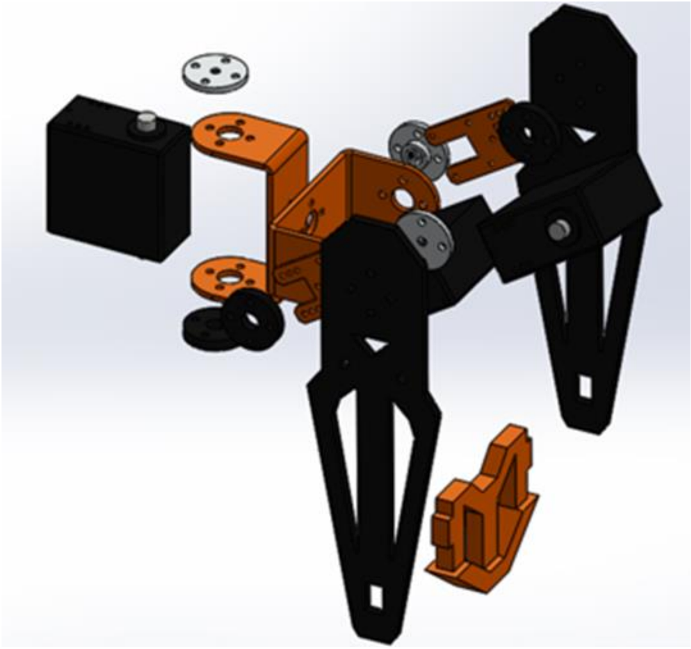

Figure 4 Preliminary parts of a limb

Figure 5 Introducing the final Prototype of Hexapod

Reference Source: Own elaboration

Results

- 36 prototypes were made in two generations,
- The first with two groups, one of 26 men and 6 women, the second of 22 men and 6 women, in the second generation 1 woman and 31 men.
- In the first generation there were 22 prototypes and in the second 14, in both generations the teams were formed by three, two and one person.
- From the 36 prototypes presented, the 22 made in the first generation had favorable results in virtual prototypes, performed better and more complex simulations, but with respect to the physical part, they operated only 70% of the prototypes presented and it is believed that it was poor planning in the acquisition of components and conducting tests.
- In the second generation 14 prototypes were obtained, of which they worked entirely with the practical part, this is assumed to be due to better planning of their projects, it was also emphasized on making a previous acquisition of components, and the mechanical part was mostly with 3D printing, since they were mostly mobile robot projects.

The following evaluation was performed on each prototype:

Table 2 Evaluation for each of the prototypes

Description		**Evaluation**		
Mechanical device	Complete with physical movements	Assembled, but doesn't move everything as it should	Parts manufactured and/or assembled with details	Only unassembled parts are missing parts in assembly
Amount	30	6		
Electrical system	Working on PCB card	Powered on protoboard	Assembled circuit	Design only
Amount	27	5	4	
Control system	Implemented (degree of difficulty)	Programmed	Designed	Diagrams and basic information
Amount	15	13	5	3
Interface	Implementado	Programmed	Designed	Diagrams and basic inforamtion
Amount	27	5		4
	Good presentation	Complete information	Basic	No complete
Operating manual	31		5	
Maintenance manual	36			
Written work	Complete	Last chapter missing	Incomplete chapters	Disordered
Amount	26	3	4	3
Poster	36			

Conclusions

- Functional prototypes can be obtained within a 6-month school period if a methodology with specific objectives is followed.
- This set of activities was implemented with undergraduate students and nowadays is been worked with graduate students, who must obtain better results by dedicating themselves in longer time to the research and construction of their prototypes.
- Several of the projects can be improved and even marketed or patented by changing the used materials, since as it was mentioned, they are school prototypes and the budget is reduced compared to an industrial one.
- In the written work, a cost analysis was also done, so that students verify that a prototype is not always more accessible than an existing one and thus demonstrate that it should be designed with a design in mind to make a functional product and not just a device to sell.

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