Algorithm to Develop Mechatronic Devices
to Help People with Muscular Dystrophy

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Abstract

Scientific progress has allowed the development of technological equipment that supports the treatment aimed at people suffering from muscle deficiency. From The Pilot University of Colombia a methodology algorithm was generated for the design and implementation of these equipment, commonly called technical aids.

The proposal of a methodology of the design and implementation of technical assistance devices focused on people with muscular dystrophy, is based on the design of a descriptive study and emphasizes the systematic methodology for product development. The proposed algorithm refers to the set of techniques, procedures and documentary supports used in the design of technical assistance systems, where diverse aspects are integrated in such a way that the overall process is logical and understandable.

The algorithm includes the development of four methodologies, which begins with the research process then the mechanical device continues with the electronic system and ends with the communication system. Thus, guidelines are given to generate each of the components of the system and achieve a functional device.

Having an ordered set of systematic operations which contains a series of specific guidelines for the execution of activities where a series of stages are taken allows finding the solution to a type of problems.

In the area of physical rehabilitation, medical knowledge is combined with engineering knowledge to obtain technological solutions that facilitate the work for people with physical disabilities.

Keywords: Technical aids, Medical rehabilitation, Exoskeletons
Introduction

There are hereditary diseases that cause muscle weakness and loss of muscle mass, such is the case of muscular dystrophy. It has recognized more than 30 diseases of this type, being the common denominator the weakening of the muscles and the loss of ability to walk. There is no effective treatment to reverse the disease, but the symptoms can be controlled to prevent complications [1].

Among the procedures used to treat muscle weakness, improve joint mobility, control the pain, improve the function of different affected systems and therefore the quality of life of an individual, there is physical rehabilitation where is include physiotherapy, therapy speech, orthopaedic devices, surgery and medications, among others.

Activities as simple as raising the arm to eat or brushing your teeth are a challenge for people with dystrophy due to the decrease in strength, lack of mobility, among others. However, assisted with technology has developed multiple options to improve their quality of life.

In low- and middle-income countries, only between 5% and 15% of people who need assistive devices and technologies have access to them. Production is scarce and often of poor quality. There is a shortage of trained personnel to manage the facilitation of such devices and technologies especially at the rural level. In many places where access would be possible, they are prohibitive price [2], [3].

In the Convention on the Rights of Persons with Disabilities (articles 20 and 26), resolution WHA58.23 of the World Health Assembly and the Standard Rules on the Equalization of Opportunities for people with Disabilities highlight the importance of support devices.

States are requested to promote access to assistive devices and technologies at an affordable cost and to provide training to people with disabilities and to professionals and staff working in habilitation and rehabilitation services [3].

The design and development of support products allowed for systems that complement each other to ensure environments, products and services that facilitate personal autonomy in basic and essential tasks such as eating. In addition, they help in muscle training and brain development [4], [5].

Physical rehabilitation requires machines where the patient exercises, traditionally they have been robust machines that are located in offices or rehabilitation centres, but it has been seen that patients find these cold and boring places, therefore new equipment has been developed and systems in the area. Researchers from various disciplines are designing teams together with protocols that allow patients to perform rehabilitation exercises from home, with patients being continuously monitored.

In this way, a health specialist monitors the current progress of the person and establishes new rehabilitation routines remotely and can also store the data in a database to track and draw conclusions from the performance of the therapies about the person.

The developed machines must be attractive for the user as well as functional, intuitive operation, low cost, among others [3].
The synergistic integration of mechanical processes, microelectronics and information processing opens new possibilities for the design of processes as well as for their automatic control. As the interrelationships during the design play an important role, the simultaneous engineering has to take part from the beginning. Mechatronics as engineering allows the integration between different disciplines, is optimal at the time of generating hardware-software solutions, where there are mechanisms, electronically controlled and with communication systems [6]–[8]. Then, to obtain satisfactory results a systematic design is required, hence this document proposes an algorithm as a methodology to develop mechatronic devices as technical aids for people with physical disabilities.

**Methods**

To obtain mechatronic devices as technical aids for people with reduced mobility, procedures, methods and techniques are required through which the solution to be implemented is selected to respond to a technological need. Once the device is available, the results should be evaluated, analysed and interpreted. Mechatronic devices, like technical aids, have three fundamental parts: mechanical part, electronic part and the communication system, in Figure 1 the relationship between them is observed.

![Figure 1. Parts of a mechatronic system that helps people with reduced mobility](image)

The machinery, a mechanical part that includes the mechanism is responsible for transforming the energy to do a job as well as to carry out the work; thus, the
mechanics include a set of pieces or elements that fit together and use energy to do a job or fulfill a function [9]. This machinery must be efficient, light, multitasking, electronically reprogrammable, capable of carrying out a variety of movements or tasks by autonomous means; this notes that the design of mechanisms is a field of microeconomics and game theory, where one considers how to implement a system that responds with optimal solutions to a problem posed, involving multiple agents each one with information and input to the solution [10], [11].

The electronic part includes the combination of electronic components organized in circuits, designed to control and take advantage of electrical signals. The electronic design allows to obtain a circuit either for storage, transport or transformation of information. All electronic development involves three parts related to each other for good operation: hardware, firmware and software [12], [13]. The hardware is the physical aspect of the devices, they are the electronic components, sensors, actuators, electronic cards, printed circuits or PCB, among others. The firmware refers to instructions or permanent programs of computer devices, this programming is very low level it is stored in memories present in microprocessors, microcontrollers or embedded systems, the characteristic is that the common user cannot access or alter programs. The software is the set procedures, rules, documentation and data that make up programs and routines are resident in devices such as computers, smart phones, tablets, etc., allow to perform specific tasks on these devices. In the electronic devices the hardware executes the indicated operations through codes by the firmware, can be reading of sensors, activation of actuators, storage of information, reception and transmission of data, to name a few; the firmware follows the software's orders, makes the decisions according to the programming it contains, interconnects hardware and software, etc.; the software performs the tasks of data processing, visualization of the same in a user interface, and in general the macro processes of the device. The communication system allows transferring information from one point to another between circuits, electronic and mechanical systems carries out supervision and control tasks, that is, it is responsible for transmitting the signals to intercommunicate the different parts of the mechatronic devices.

To achieve its function, it has three basic components: Transmitter, responsible for sending the message to the channel in the form of a signal; Transmission channel or medium, electrical link between transmitter and receiver; and Receiver, receives the desired signal from the channel.

**Results and discussion**

The process of developing technical aids for people with disabilities, involves several stages related to each other, we have the investigative process, the mechanical device, the electronic system and the communication system. Then, an algorithm has been developed that combines the combination of methodologies for each stage: a methodology for the development of the research process, another for
the design and implementation of the electronic device, one more for the communication system and another for the design and development of the mechanical device. The Figure 2, shows the different processes to take into account to develop the devices.
It begins with the study of the problem, the needs to be covered, the type of disability, the muscle-skeletal involvement, the target population (age range, sex). As a consequence, to start it is imperative to have the general approach of the research. Before, the theories, concepts and/or definitions that give the floor to the project are established, as well as the state of the art of the subject of the laboratory. Then the methodological design of each element is defined: starting with the design and construction of the mechanical device, from there the communication system is determined, as well as the design and construction of the electronic system.
In the mechanical design, the structures of the system, the materials to be used and the associated manufacturing processes are defined, taking into account the techniques and technologies to which they have access and the cost. To achieve a device that satisfies the requirements satisfactorily, a series of steps must be performed, among which are: determining the mechanical specifications of the prototype; obtain a model, through the design, simulation, evaluation and optimization of it, here the preliminary schemes and design forms are elaborated, evaluated with respect to technical and economic criteria and the design that provides the most benefits is selected; then a preliminary scheme is reached, where the design of the forms is completed, verification of errors is made, cost effectiveness and the pieces are preliminarily listed and documents for production; finally, the final scheme is reached, with final details, detail drawings and simulation of the system.

Figure 2. Methodology for obtaining Technical Assistance Devices aimed at people with disabilities
Once this phase is done, there will be a general outline of the system, together with a report on the function, duration, manufacture, assembly, operation, cost and safety of the mechanical prototype.

The communication system allows the efficient management of information between the mechanical part and the electronic part, for this purpose the transmitter, the communication channel and the receiver must be proposed, in such a way that it is achieved: have a reduced time in the total amount of data transmitted per unit of time, low probability of errors with the loss of information or erroneous information, propose the probability of detection of errors to increase the effectiveness of the controls and ensure good connection. For the design of this system, the following is done: Establishment of the necessary technical needs within the communication on the device; Design of the prototype of the communication system with the electronic elements that provide the required solution; Checking the performance of the design made with simulation software; Implementation of the hardware and software that perform the communication; Test and verification of communication operation between the mechanical and electronic part.

The electronic part is obtained once the following steps are completed: Agree on the requirements and technical specifications of the system; Describe the alternative solution through a block diagram, a flow diagram, among others; Establish the elements of the device and determine the hardware-software tools to be used; Verify the achievement of the same, in terms of cost and acquisition; Design the electronic circuit, simulate and verify the operation of the design; Physically implement the design; Experimentally validate the implementation.

Conclusions

The methodological proposal includes professional people from different areas of knowledge, among them personnel from the health area, engineers, architects, etc. With this interdisciplinary group, it is possible to offer robust, low-cost aids and easy access to the people who require them.

It is necessary to validate the proposal in the development and obtaining of different devices, in this first test of the algorithm the expected results were reached.

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