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Development of a Graphic User Interface Focused on Multicriteria Analysis among a Plethora of Passive Exoskeletons to Improve the Social Inclusion of Infants in a Smart City

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Abstract. Passive exoskeletons are portable devices that have beneficial functions that can address ergonomic needs taking advantage over other technological supports. They were developed to multiply human power. Passive exoskeletons have been introduced in some industrial environments, but there has been relatively little research that has examined the possible benefits, drawbacks, and tradeoffs of using the exoskeleton in a workplace. These exoskeletons require different approaches towards compliance with requirements such as use, acceptability in the workplace and possible security problems among others. Consequently, the present investigation has planned to evaluate different passive exoskeletons based on criteria such as: cost, multitasking, performance, physical demand, and influence of the mass of the tool. The criteria will be modeled and evaluated with the AHP methodology (Analytical Hierarchy Process), in order to support the acquisition decision, in the present investigation a multicriteria analysis is carried out that will allow identifying which would be the best exoskeleton of its type and how it would help children with some type of motor defect in a Smart City with regard to their social inclusion.

Keywords: passive exoskeletons, usability, multicriteria analysis, AHP.

1 Introduction

In recent years, a series of technological measures have emerged that offer help to the operator to perform certain industrial tasks of lifting, moving and unloading, such as: cranes, forklifts, and robots, but with limitations to access small places. Then, the exoskeletons appear as an alternative to counteract some of these limitations. Exoskeletons are collaborative robots that have beneficial functions that can address industrial ergonomic needs such as postural load compensation, the requirement of upper limbs or adaptability in the choice of tasks [1]. Exoskeletons are defined as portable mechanical structures that improve a person's strength, and reduce their exposure to the associated physical demand [2]. Thus, the advantages of exoskeletons over other robotic solutions are that they are intuitive to use, and are operated without requiring a robust and expensive infrastructure [3]. Then, the exoskeletons are a technological strategy that compensates the physical load without taking up space and allowing maneuverability in places where other technologies cannot operate.

Despite the fact that numerous work-related exoskeletons are commercially available and have been introduced into some occupational environments, there has been relatively little research that has examined the possible benefits, drawbacks, and compensations of exoskeleton use in a workplace [4]. The main benefit of the exoskeleton is a good fusion between the human flexibility and the robot improving the power, without the need of teaching or programming of robots; in addition, they can be used when others traditional solutions are not usable or effective [5]. Then, as a result of the growing tendency to use exoskeletons in the industry, where economic benefits are frequently a key to decision-making, and because they have been evaluated in terms of the reduction of physical demand, what was considered useful to evaluate its effectiveness in terms of performance and reduction of the risk of injuries [6].

An exoskeleton can be defined as an external and portable mechanical structure that improves the power of a person, and which can be classified as "active" or "passive" [7]. An active exoskeleton is composed of one or more actuators (for example, electric motors) that actively increases power to the human body, while a passive system does not use an external power source, but uses materials, springs or dampers with the ability to store the energy of human movements and release it when necessary [8]. Therefore, commercially developed exoskeletons are mainly passive in nature, with the aim of reducing the physical load during dynamic lifting and static flexion [9]. These exoskeletons, passive or active, require different approaches towards the fulfillment of requirements such as use, acceptability in the workplace and possible security problems [10]. Then, in the mechanical design of these systems, mobile ranges, safety, comfort, low inertia and adaptability should be especially considered [11]. So, usability is a key factor to take into account in the selection of technology. Usability is defined by [12], as the extent to which a system, product or service can be used by specific users to achieve specific objectives with effectiveness, efficiency and satisfaction in a specific context of use. Then, usability is as important as the design and technical characteristics with respect to high customer satisfaction and future sales [13]. So, when purchasing a team of these, it is necessary to systematically evaluate different criteria based on a methodology to support the decision. For example, [14] they applied the AHP in their study, mainly due to their inherent capacity to handle the qualitative and quantitative criteria used in equipment selection problems. Consequently, the present investigation has planned to evaluate different passive exoskeletons based on criteria such as: cost, multitasking, performance, weight, physical demand, and influence of the mass of the tool. The criteria will be modeled and evaluated with the AHP methodology (Analytical Hierarchy Process), to support the acquisition decision.

Table 1. Selected criteria.

Criterion	Sub-criterion	Unit of measurement	Specifications
Cost	Does not apply	Dollars	Does not apply
Multitasking	-With tool support -Without tool holder	- # of supports - # of supports	-Type of tool support -Type of arm support
Performance	-Productivity	-tasks / minute	-Standard time

Criterion	Sub-criterion	Unit of measure-ment	Specifications
	-Quality	-Milimeters	-Adjustment, tolerance allowed for the task
Weight	Does not apply	kilograms	Limit allowed
Physical Demand	-Commodity - Muscular load	-Scale Likert -Newtons	-Scale range with extremes: Dis-comfort and comfort -Force applied with and without tool
Mass influence tool	-With it -Without it	-Milivoltics -Milivoltics	-Maximum set for muscle -Maximum established for muscle
Social inclusion in chil-dren with motor disabili-ties	Does not apply	cost-benefit	Does not apply

Figure 1 depicts the parts of a passive exoskeleton with tool support [15], and Figure 2 presents the parts of a passive exoskeleton to support the shoulder [16].

Fig. 1. Passive exoskeleton with tool support.

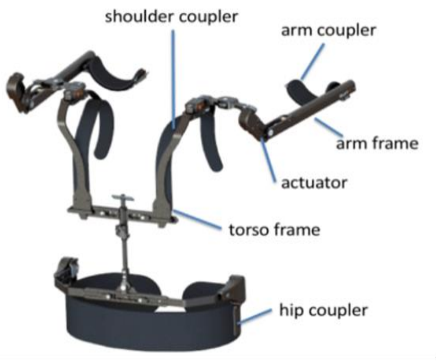

Fig. 2. Passive exoskeleton to support the shoulder.

2 Proposed Methodology

The AHP was proposed by Saaty in 1991, and it uses an objective function to add the different aspects of the problem, and its goal is to select the alternative that has the highest values of the objective function [17]. The application of the AHP procedure involves three basic steps: (1) decomposition, or hierarchical construction; (2) comparative judgments, or definition and execution of data collection to obtain pair comparison data on the elements of the hierarchical structure; synthesis of priorities, or construction of a total priority rate [18]. The weights of the criteria and sub-criteria are calculated by the AHP, where it calculates the relative importance of each criterion by means of an exploration of a multilevel hierarchy of a structure of decision making [19].

[20] presents the following decision sequence with AHP in his research:

a. Confirm the evaluation problem.
b. List the evaluation elements.
c. Establish hierarchies.
d. Establish the pair comparison matrix.
e. Obtain the eigenvector and the maximum eigenvalue of the matrix.
f. Obtain the index and the proportion of consistency.
g. Determine if the matrix of comparisons is consistent. If it is consistent, refer for evaluation. Otherwise, go back to point d.

[21] in its application of AHP for the selection of equipment suggests to keep present:

a. There is no correct hierarchy.
b. The context plays an important role for the lower hierarchical levels.
c. The factors of each level must be related to the previous level.
d. An attribute must have a name associated with its meaning and be perceived by the user as is.
e. Avoid duplication.
f. Avoid factors that generate identical alternatives.
g. A decision factor is not limited to belonging to a set.
h. The fact of moving to the comparison of pairs does not mean that the hierarchy has ended.

We propose a decision support system based on AHP, which allows analyzing diverse criteria associated with the use of passive exoskeletons, which include:

a. Cost,
b. Multitasking,
c. Performance,
d. Weight,
e. Physical demand,
f. Influence mass tool,
g. Social inclusion in children with motor disabilities.

People with disabilities also deserve to be recognized, that is why December 3 is the International Day of Persons with Disabilities. In our society we still have a hard time understanding that they are citizens with full rights and obligations, that they can perform the same jobs as the rest and that they should have the same opportunities.

The current reality is that, in general, people with disabilities have a poorer quality of life than the rest of the citizens, since their access to education is lower and, as a consequence, their labor insertion is also lower, which at the same time, it condemns them to having higher poverty rates than people without disabilities. The simple fact of being disabled carries a series of consequences that affect for life. We are in a moment in which we celebrate that a person with disabilities goes to the University and finish the race, a process that thousands of young people spend each academic year, but that seems an extraordinary fact if performed by a "disabled". All this is triggered by the fact that we still do not see it as something normal and generalized, and there is still a long way to go.

There are many who can lead a normal life, but for many people with disabilities and those who care for them, life may not be easy. Disabilities affect the whole family. Satisfying the complex needs of a person with a disability can cause a tremendous level of stress for the family, emotionally as well as economically, and often physically. It will depend on the type and degree of disability that you have. But with the policies of cuts that have been suffered in recent years it is difficult to find financial support to face the day to day of these people.

3 Design of a Graphical User Interface Associated with the Correct Selection of a Passive Exoskeleton to Improve Social Inclusion

An aspect of great relevance in our research, was not only to analyze the different types of existing exoskeletons, but to determine the functionality that each one has, as can be seen in Figure 3, and specify which could be useful to help social inclusion of childhood with motor problems.

Fig. 3. Specifications and use of different types of exoskeletons existing in the Market.

Through the implementation of an adequate and optimal graphical user interface associated with the system and composed of seven different modules can be obtained in the case of the social inclusion module, an analysis of each type of child and his motor problem, then specify the matching characteristics, then through a multicriteria analysis visualize the performance of each one of the exoskeletons that can cover the range of needs of that type of child and a visualization of how this functionary. Figure 4 shows a conceptual representation of decision making. Finally, a representation of the associated social inclusion can be observed with the performance given by exoskeleton for that particular type of motor problem, as can be seen in the ranking and matching module of our Intelligent System., as is shown in Figure 5.

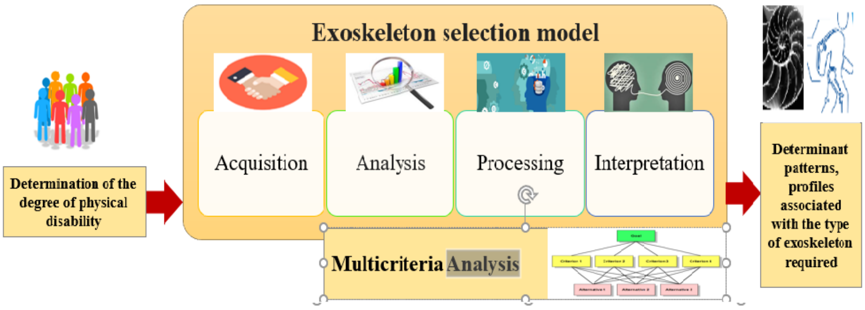

Fig. 4. Conceptual representation of decision making.

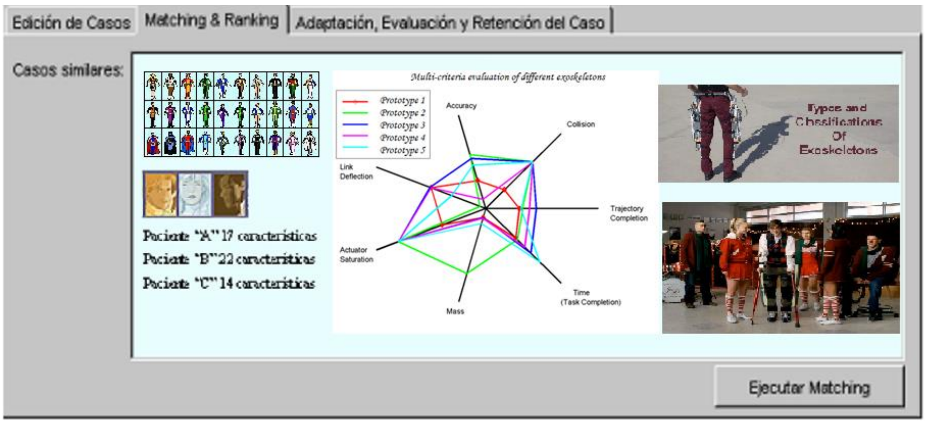

Fig. 5. Simulation module of our intelligent tool for the proper selection of an exoskeleton using multicriteria analysis.

Intelligent decision-making tools are based on multi-criteria analysis to be able to make an adequate selection of the best characteristics considering factors such as price, performance, usability, and above all the aspect of the human factor of their daily use.

4 Conclusions and Future Research

We have much to advance and overcome in this aspect, starting with the educational, social and labor inclusion of people with disabilities: recognizing that the difference in abilities among all people is a fact of social plurality, and not a handicap, as we have observed it until very recently. This change of mentality is what needs to be generalized in the whole of Spanish society and the world.

We cannot wait for the Administrations governments to change their procedures without first changing our way of thinking, because in the meantime we are missing the opportunity to take advantage of the enormous potential of people with disabilities.

If you want to contribute to this society with real changes in these issues, and educate from the base to eliminate or at least reduce discrimination or the non-inclusion of people who struggle every day with physical disability. The proposal of an intelligent tool that can help to select the most suitable exoskeleton depending on the type of motor disability.

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