Chapter

Architecture of a Telemonitoring System for the Mobility of the Elderly in Wheelchairs Supported by Internet of Things Technologies as a Component of a Smart City

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Abstract

Digital transformation and the entry of new technologies in industry are changing the way of mobility and production in large cities. The industrial revolution 4.0 comes hand in hand with technology and advances in this field. The Internet of Things (IoT) is one of the innovations that offers the most versatility to industrial companies in the main cities as a relevant axis for supporting rural areas of the country. This Technology enables Cities to allow mobility and movement for all, regardless of their physical or mobility conditions. This chapter presents the proposal of the project "Safe mobility in conventional wheelchairs in public spaces from smart cities", in which the creation of a prototype of coupling to wheelchairs in people with disabilities in their lower extremities is expected. Through the caterpillar traction system, to facilitate the ascending and descending of stairs safely and reliably called Wheelchair Adapter. It is intended to review two relevant elements for this type of people, such as health and mobility. The design and implementation of an Architecture of a Telemonitoring System for Older Adults in Health and Mobility in their wheelchair supported by Internet of Things Technologies (IoT) generally called RobotUp_IoT. Its purpose is to efficiently monitor both the health and wheelchair movement of older adults with disabilities in their lower extremities. Therefore, an analytical and predictive methodology is proposed with the support of the Build Information Modeling (BIM) process and the 4.0 industry in the IoT technique, in order to build a conceptual 3D model and its generation of tests for its respective implementation and implementation of this architecture. Heelchair Adapter and it is expected to incorporate the health part through Telemonitoring for seniors between 2020 and 2022 contributing to other solutions and research in this regard.

Keywords: disability, obstacles, sensors, motors, quality of life, stairs, cloud

1. Introduction

The Internet of Things, or IoT in English, is a tool created by the advances in Information and Communication Technologies. This technology can be adapted to a myriad of industrial processes. It also allows integrating a processing, storage and communication system between physical objects in a city that are connected to each other. Using sensors, the Internet of Things makes it possible to collect data in a simple way and for example send alerts if something does not work correctly. The potential of the Internet of Things is in the use of another tool of digital transformation: Big Data. An essential technology to facilitate decision-making based on the data collected.

Every time we live in a more interconnected world. The number of connected devices has been growing exorbitantly globally as technological improvements and cost reductions in wireless communications have enabled businesses, manufacturers, industries and smart cities to connect their products to the Internet of Things (IoT).

In this sense, citizens have at our supply a wide range of services that can make everyday life easier. There are numerous architectures to deploy IoT platforms in different contexts and levels, such as within the home, healthcare, business, municipal, national or even global level. The most direct impact on the lives of citizens involves our cities and interconnects people and services, in short, it transforms a city into a Smart City [1].

The "Smart City" or "SmartCity" can be seen as an instrumented, interconnected and intelligent urban ecosystem. Instrumented refers to the ability to capture and integrate real-time data on city life through the use of sensors and mobile devices (IoT technology). Interconnected means the integration of these data in an urban computing platform that allows the communication of said information between the various services of the city. Smart refers to the integration of complex analytics, modeling, optimization and visualization of services to make better operational decisions for the city.

Today there is an analysis of assistive technology services, according to the class and subclass of assistive technology products formulated. Therefore, there are assistive technology devices or products that are classified according to Smith [2], who presents high technology (high-tech) versus low technology. High technology refers to devices that are made up of electronic devices or that are not for everyday use today. This type of technology, having an exotic appearance, represents the idea of what people understand by technology; Examples are cell phones, electronic agendas, magnetic resonance imaging devices, positron emission tomography, bio-feed-back and neuropros theses [3, 4]. On the other hand, there is low technology, which includes less complex, more common devices with mechanical or electrical drive; here we can mention home appliances, calculators, manual wheelchairs, canes and splints (Ríos et al., 2007).

IoT technology is essential for the operation of the Smart City, through sensors in charge of collecting data on the state of the city and subsequently disseminating them among citizens. IoT consists of allowing things to connect to the Internet, this achieves the generation of information, and the interaction of the physical world with the virtual world [5]. Regarding the number of things connected, the evolution of this field is observed from 2015 to 2020. In 2020 the figure of 31 billion is reached worldwide and a value of more than one billion US dollars per year is projected from 2017 [6].

Defining assistive technology products according to their level or degree of technology is important, since the costs generated by their formulation; adaptation and training vary significantly between one group and another. For this reason, in the classification below, devices that are considered high-tech have been marked with an asterisk. Obviously, as technological development is so accelerated, many devices that are considered high-tech at the moment, in a few years may be considered low-tech, such as:

- Bimanual wheelchair: two evaluations by a specialist in physical medicine and rehabilitation and five sessions of physical therapy.

- Single-sided manual wheelchair: two evaluations by a specialist in physical medicine and rehabilitation and ten sessions of physical therapy.

- Manual-operated electric motor wheelchair: evaluation, formulation and approval by an interdisciplinary team is required, consisting of a minimum of one physician specializing in physical medicine and rehabilitation, physical therapist, occupational therapist, social worker, psychologist and a representative of the EPS. Approval will be given in an interdisciplinary meeting, where the number of sessions to learn how to manage it will be defined.

- Powered-drive electric motor wheelchair: evaluation, formulation and approval by an interdisciplinary team is required, consisting of a minimum of a specialist in physical medicine and rehabilitation, physical therapist, occupational therapist, social worker, psychologist and a representative of the EPS. Approval will be given in an interdisciplinary meeting, where the number of sessions to learn how to manage it will be defined.

- According to the Colombian population profile of DANE 2017, the elderly population has difficulties in appropriately affected lower limbs of 34,000 (9.7%) in men, 28,007 (8.5%) in women for a total of 62,007 (9.1%)

The IoT is of great importance being the first real evolution of the Internet; considered as a great leap that will lead to revolutionary applications that have the potential to significantly improve the way of living, learning, working and entertaining people [7].

The problem faced by older adults in wheelchairs is presented in two fundamental aspects such as health: presence of underlying tissue called pressure ulcers, as they remain in the same part of the body for a long time; Dermatitis that also responds to a lesion on the skin as a sequel to fecal and/or urinary incontinence; the lack of control of the supply of drugs in the time allocated; as well as the inadequate programming of the doctor's assistance for the control check-up and mobility in aspects such as: dependence to go from one place to another, obstacles impossible to overcome, going up or down steps with the wheelchair, among others.

These lead to family members or friends being concerned about the quality of life of their family member and on many occasions they go to the care of nurses or hospitalizations that what they do is affect the mood and health of the person at high costs for some of their relatives [8].

In **Figure 1**, the previous situation is observed, in terms of internal or external mobility of adults who are in wheelchairs. There it is visualized that at a given moment they do not know what to do or who to call, they only have to wait for their relatives or friends to help them in this regard.

Due to this problem, the following research question arises: How to contribute to improving the quality of life conditions and reduce the risk situations that the

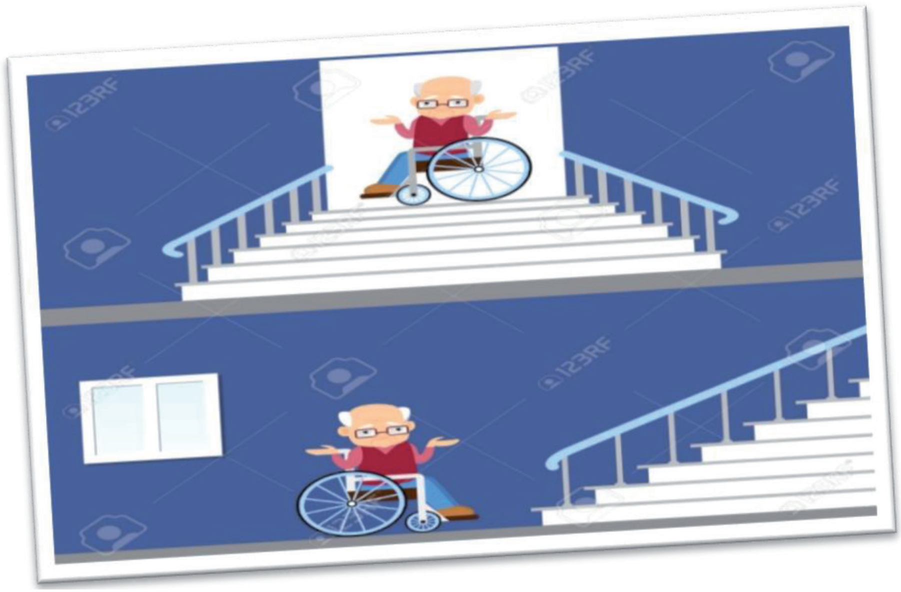

Figure 1.
Situation of the elderly to achieve the ascent and descent of the stairs. Source: Authors.

elderly who are bedridden in a wheelchair may present, enabling timely attention, their care of permanent form and your independent mobility? Risk situations can be prevented with viable technological solutions such as an Architecture of a Telemonitoring System for Older Adults, which can improve the quality of life of older adults, since it will not only have benefits for them, it will also allow them to your family members feel calm and safe, because they will have a reliable way of verifying the state in which their loved ones are.

The objective of the study is to manage a monitoring service for the health and mobility of older adults who are bedridden in a wheelchair through Internet of Things (IoT) technology with the use of sensors for the detection of data, internet for the transmission of these and a mobile or web application for the visualization of the information, in order to support the prevention of new diseases and control the diseases that the elderly already suffer and at the same time achieve their independent mobility inside and outside your room.

2. Theoretical framework

According to an analysis of the experience of the Australian System of Care for Older Adults, which for Pérez [9] is considered one of the most advanced among experts and public policy analysts and in which he exposes three fundamental pillars, among which is the development of efficient operational skills, highlighting as one of these efficient skills the importance of technology and innovation as key factors to improve the effectiveness of the system. Successful experiences of technological innovation that range from the implementation of computerized systems to solutions such as tableware at home, which defines it as a type of permanent video-conference with the patient at home, reminding her to take her medicines, offering her a health channel.

An e-Health project at the national level is the Mobile Telehealth System, designed in the College of Engineering of Antioquia by Garcia and Torres [10], it consists of a system composed of three main blocks that are: Input subsystem which by means of Sensor collects the patient's vital signs and sends them to another block, the Local subsystem, which is made up of different devices and elements that receive this information and send it to the third block, the Remote Subsystem, which is responsible for storing the information in a database of data and sample it through a website.

In Colombia, this type of project related to telemedicine and e-Health has had very little demand, it is a recent technology and they are projects that are carried out as a commitment to innovation in these fields of health and mobility. At the regional level, no reports of projects aimed at monitoring older adults were found, this serves as motivation for the implementation of projects such as the Architecture for the Telemonitoring System for Older Adults who are in wheelchairs mentioned in this research and to be able to carry out a significant contribution for the elderly in the city of Bogotá.

3. Methodology

The approach of this applied research of an analytical and predictive type with the use and use of IoT technology, with the support of a descriptive study that allows monitoring the elderly who is in a wheelchair, through detection of your data and in this way send a notification message to alert your family, friends or doctor to avoid complications that endanger the health and mobility of older adults.

An evaluation instrument called a survey will be established to a sample of Twenty-five (25) people who are elderly in wheelchairs in their homes in the city of Bogotá in the town of Tunjuelito, during the period of 2017–2018, at as well as an unstructured interview with a focus group of relatives and friends with elderly people in permanent wheelchairs. A data analysis is established and the disposition of the technology to the need to implement the architecture referenced in this research is determined by means of the Rational Unified Process Architecture (RUP). This process consists of the realization of a software from UML, which will be built in four phases: start, elaboration, construction and transition [11].

A partial investigation will be implemented on the population directly affected by mobility in this case of people disabled in wheelchairs as older adults [12].

3.1 Design of the methodological proposal

It will be made up of four fundamental stages such as:

- **Stage 1**. Technique of IoT and Telemonitoring for Older Adults in wheelchairs under the aspect of health and mobility.

- **Stage 2**. Identification of the hardware and software requirements necessary for the implementation of the Telemonitoring System for Older Adults located in the wheelchair as a Hub platform.

- **Stage 3.** Design of an architecture of a Telemonitoring system with the use of the IoT technique for older adults who are in wheelchairs, in order to provide security and a low-cost mechanism due to the use of available technologies that allow the user to stay informed at all times of the health status of his family member or friend.

- **Stage 4.** Implementation of the functional prototype of the Telemonitoring architecture, through testing and adjustment in order to correct the weak points of said architecture

4. Expected results

It is expected that by applying IoT technology in this research, it is possible to improve the quality of life of older adults who are in a wheelchair [13]. For this reason, a domain model will be created in which the concepts and associations considered important in a Telemonitoring Architecture for older adults who are in wheelchairs from health and mobility will be identified [14].

This monitoring is done by means of the wheelchair with the use of sensors generating medical information, which in turn presents early alerts, which can be received by the attendants or the medical person through a mobile device, where will make the reminders of medical appointments and medications to later receive notification when the due date of these is close. This chair will also allow the independent mobility of the elderly with disabilities, since it will have a wireless connection and will use the IoT for monitoring according to comfort, performance, maintenance needs and location.

In **Figure 2**, the Domain Model of the architecture of a Telemonitoring system for older adults is observed. in which it can be seen that everything begins with the doctor's assessment of the elderly, this allows determining that this patient requires constant monitoring, the monitoring is carried out by generating medical information, which in turn generates early alerts, said alerts can be received by caregivers or medical staff through a mobile device, in which it is also possible to carry out the management of reminders of medical appointments and medications to later receive notifications when the date of compliance with these is close.

In **Figure 3**, the three levels with which the Architecture proposed in this investigation will be worked are observed: Sensing. In this layer the necessary elements are implemented to carry out the obtaining of the data through the elements of sensors, wearables, among others; Networking and Data Communications: The data sensed in the previously described layer are sent through a medium for subsequent analysis, in this layer are the devices and elements necessary to send this data through the internet, in this layer you can find servers, databases, protocol adapters, among others, this layer acts as a link between the Sensing layer and the Services or Applications layer; and Services / Applications: This layer,

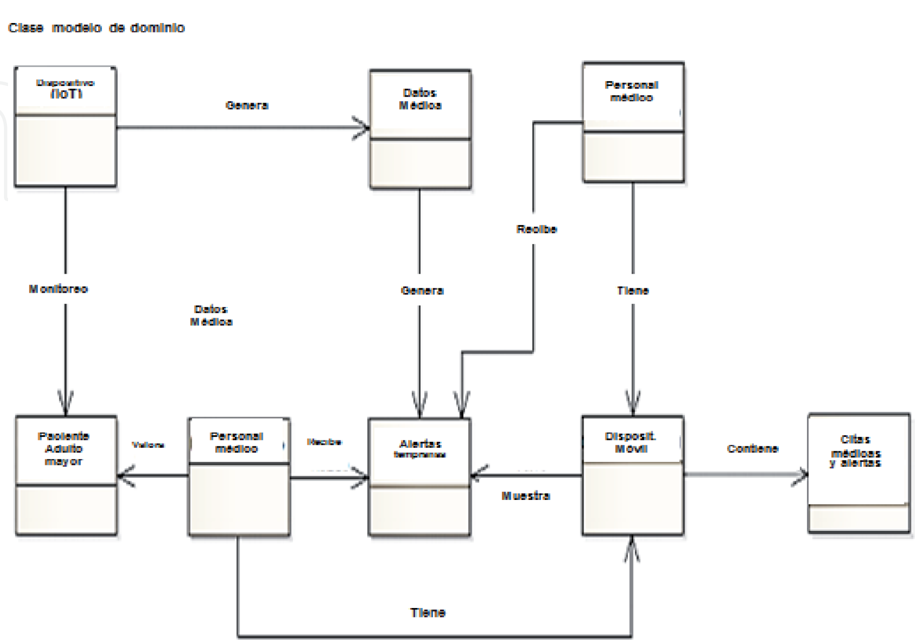

Figure 2.
Domain model of the architecture of a Telemonitoring system for older adults. Source: IEEE P2413 project, http://standards.ieee.org/innovate/iot/.

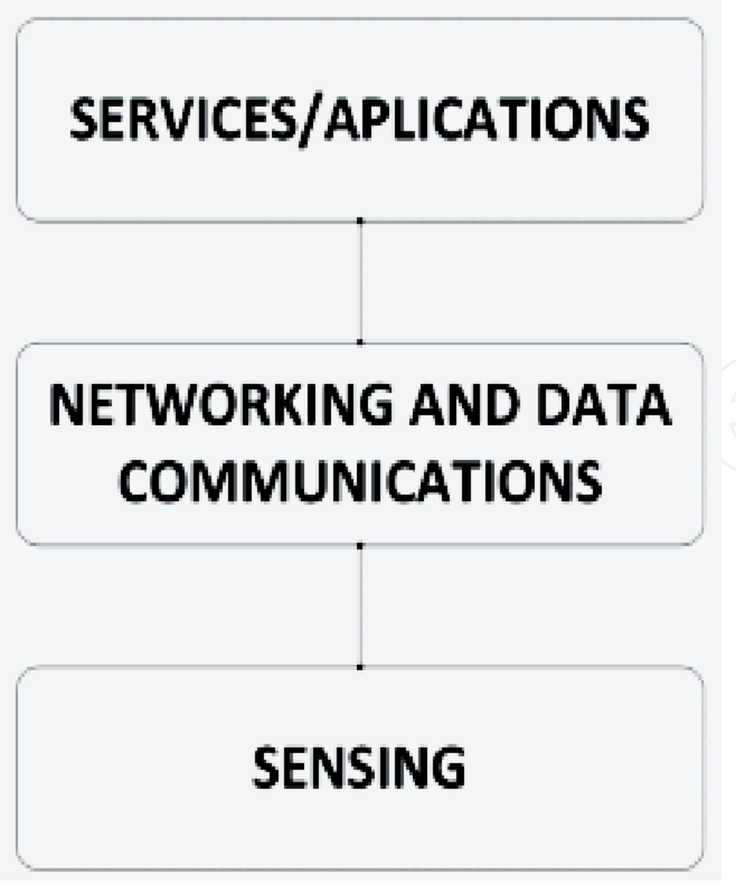

Figure 3.
Levels of an IoT architecture. Source: Authors.

Based on the elements of **Figure 3**, the prototype of the computational system is built based on the IoT business model, allowing the good performance of the proposed Architecture.

This IoT business model is made up of three fundamental layers:

- Detection Layer: It is achieved by means of the components in charge of the sensing information, as well as the information to be sent to the next layer of the model.
- Network and Data Communication Layer: It consists of a data knowledge base; a server on which the web services are stored; and connectivity that enables communication between the detection layer and the service / application layer.
- User layer: It is where it allows the hosting of the services to be offered by the system, it is known as services / applications, such as notifications, elderly information, movement indicators, parameterization of actions and administration of the platform.

For the mobility aspect, the wheelchair uses IoT technology that includes a Global SIM card, a communication center can be established in the cloud.

4.1 Examine the architecture

The different parts of the architecture must be examined and evaluated separately and allow ease in visualizing the complexity of the system, responding to interested parties, clients, programmers, engineers, among others. Therefore, the

4 + 1 views model proposed by Philippe Kruchten is used, such as the view: logic, deployment or development, processes, physics and scenario views. Through the IoT architecture model composed of three levels proposed by IEEE P2413, it will be possible to meet the objectives proposed in this research.

4.1.1 Mobile device

It is the technological device that will allow the family member or friend to receive alerts or notifications from the elderly person who is in the wheelchair. These alerts come from the Google GCM service, allowing you to perform an action and thus prevent an eventuality affecting the health or mobility of the Elderly. According to the authors Liu, Huang and Chen [14]. They highlight the importance of managing and receiving notifications for reminders of medical appointments and drug consumption. This application is only for mobile devices with Android operating systems, where each of the functionalities that can be carried out through the mobile application must be explained in detail.

4.1.2 Architecture evaluation: Case study

The implementation of a test mechanism of the Telemonitoring Architecture for Older Adults who are in wheelchairs should be carried out, which follows the guidelines of the model, aimed at monitoring the health and mobility status of the elderly, managing and receiving notifications of medical appointments and medicines, view statistics of alerts and information on the sensing of the elderly, obtaining the benefit of constant care, keeping a correct control of the assigned treatments, intervention in case of situations that put health at risk and mobility of the elderly. The purpose is to find the most outstanding benefits of the implementation of this service model such as: economy, security, reliability and risk reduction among others.

Regarding mobility, physical aspects of the chair should be evaluated, such as: seat position, cushion height, battery level and maintenance requirements and GPS location.

4.1.3 Product already obtained in the first phase of the project

The Wheelchair Adapter is a mechanism that adjusts smoothly and safely to conventional wheelchairs, helping people with disabilities in their lower extremities to navigate different terrain, mainly the ascent and descent of stairs.

4.1.3.1 Procedure

- **Base:** Resistant metal base which will keep the other components that make up the Wheelchair Adapter.

- **Gears:** Four gears which allow to adapt and generate the movement of the track system.

- **Caterpillar motors:** Two motors located on the internal sides of the metal base connected by chain systems to the shafts that carry the gears, which in turn are attached to the tracks.

- **Caterpillars:** Element in the form of an elongated chain, which allows the firm adherence of the Wheelchair Adapter to different terrains.

- **Ultrasound sensors:** Two sensors located on the front of the Wheelchair Adapter that allows it to be located in the environment it is in.
- **Support:** Metal plate which allows the conventional wheelchair to recline and generate stability in movement
- **Ramp:** Metal plate whose function is to provide quick and easy access when adapting the conventional wheelchair with the Wheelchair Adapter.
- **Adjustment system and Angle:** It allows locating the wheelchair and the person at an adequate and safe angle to start the ascent and descent of stairs, this is made up of a structure with a system of rails powered by two motors located behind the backrest.
- **Cortex microprocessor:** Microcontroller which saves and executes the programmed instructions for the sensors and motors that perform the movements of the Wheelchair Adapter.
- **Battery:** 7.2 volt battery which allows to power the motors and sensors of the Wheelchair Adapter.
- **Triangle rims:** Triangle-shaped structure with tires at each end that provides additional grip on difficult terrain, ascending and descending stairs

Movements

- 2-wire motor 393
- Shaft collar
- Shaft coupler
- Shaft, 3 ″long
- Plain bearing
- Spur gear, 12 teeth
- Spur gear, 60 teeth
- Spur gear, 84 teeth
- Wheel 4″

Structure

- Bar, 20 holes
- Chassis bumper (20 holes)
- Chassis rail (16 holes)
- Channel C, hole 1x2x1x15
- Channel C, hole 1x2x1x20

Electric

- 7.2V NiMH 3000mAh robotic battery
- Smart charger and power cord
- NiMH AAA rechargeable battery (6 pack)
- 8-Bay AA / AAA Smart Battery Charger
- Motor controller 29
- Battery strap (2-pack)

Electronics

- VEX ARM® Cortex®-based Microcontroller
- USB AA tether cable

Control

- VEXnet Joystick
- VEXnet 2.0 key
- VEXnet Battery Backup Holder

Hardware

- Screw, 8-32 x 1/4 ″long
- Screw, 8-32 x 1/2 ″long
- Screw, 8-32 x 1 1/2 ″Long
- Locking screw, 6-32 x 1/4 ″long
- Locking screw, 6-32 x 1/2 ″long
- Nut, 8-32 Keps
- Shaft Spacer, Slim (4.6mm)
- 4″Zip Ties
- Bearing accessory rivet

Equipment

- Tool, hex wrench (5/64 ″)
- Tool, hex wrench (3/32 ″)
- Tool, VEX open end wrench

Sensors

- Bumper switch (2-pack)
- Limit switch (2-pack)
- Potentiometer (2-pack)
- Line Tracker
- Ultrasonic range finder
- Optical Axis Encoder (2 Pack)

4.1.3.2 Final product explanation

In **Figure 4**, the Wheelchair Adapter, with the help of the motors located in the upper rear part, allow through a slow and safe movement that the rails located on the sides raise the platform where the conventional wheelchair is located, so that at the time of the ascent and descent is left with a 90 degree angle for safety and comfort.

In **Figure 5**, you can see the Wheelchair Adapter, with the help of the complex system of equilateral triangle-shaped rims, it allows you to have a better grip on each obstacle in your environment, generating more security when moving.

In **Figure 6**, the Wheelchair Adapter is observed, thanks to its caterpillar traction system and its 45 degree angle allows generating the ascent and descent of stairs and with its sophisticated caterpillar design it allows to face any terrain.

In **Figure 7**, the Wheelchair Adapter is observed, it presents the mobility operation of the chair during the ascent and descent, as mentioned above, the prototype generates a lot of stability thanks to its caterpillar system and its triangular wheels,

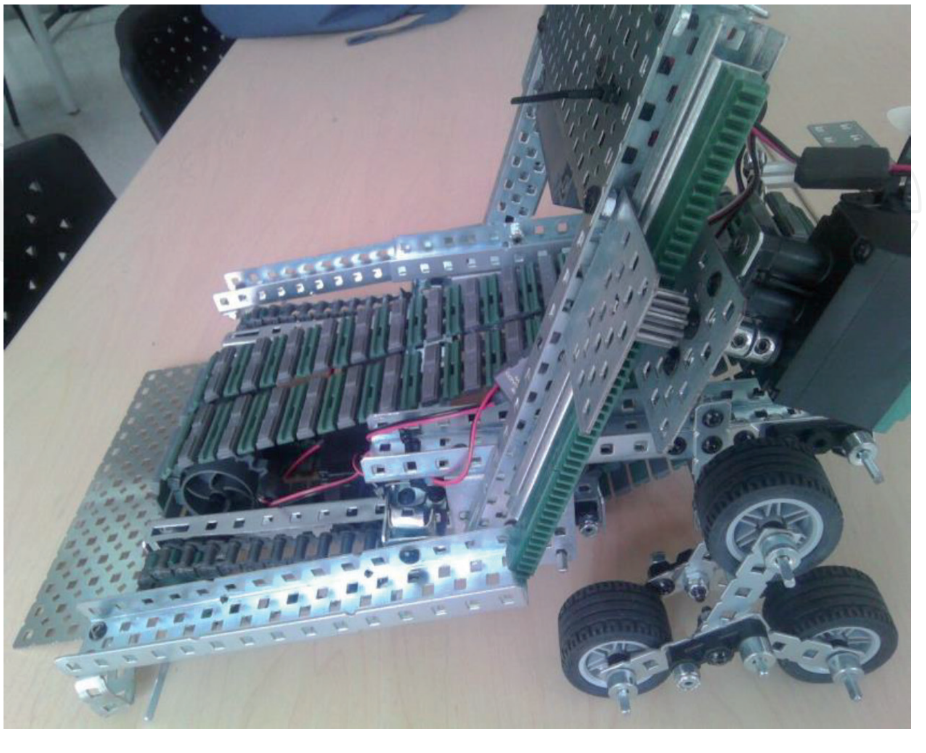

Figure 4.
Prototype of the chair of wheels.

Figure 5.
Chair of wheels with rims in shape of angle.

Figure 6.
Chair of wheels with design of caterpillars.

as well as generates security with the 90 degree position of the person by its side rails and total dependence thanks to the ultrasound sensors that identify the possible obstacles to overcome.

5. Conclusions

When investigating a little more about the difficulties that people with disabilities present in their lower extremities, there are some areas in which conventional wheelchairs do not have the necessary equipment, it is proposed to start with a prototype

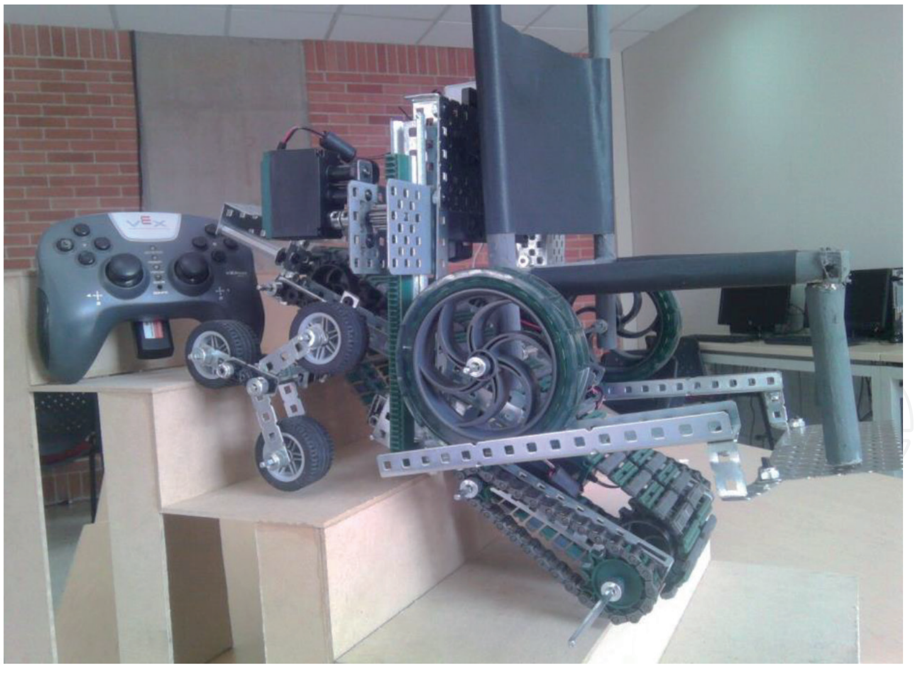

Figure 7.
Up and down movement of the wheelchair. Source: Author.

which can be adjusted accordingly. Fast and safe way, with the least physical effort to conventional wheelchairs, which solves this problem and facilitates the movement of these people for the moment when ascending and descending stairs.

When starting with the adapter prototype designs, many ideas were postulated that were conclusive as the variables were established to generate a safe, comfortable and fast tool, resulting in an adapter prototype that not only meets its objective, but also that provides an expertise to the user of comfort, security and confidence.

It is expected to work with the cloud system for data processing and permanent connection with the wheelchair and computer-assisted algorithms for the mobility and health of the patient.

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