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Initial strategy of an assistive technology for rehabilitation and monitoring of elderly patients

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ABSTRACT

This article presents an initial assistive technology strategy for the rehabilitation and monitoring of elderly patients, focused on lower limb muscle recovery, from a condition of low gait stability to recovery without the use of crutches. The project is in progress, and its first module, the recovery one, measures the flexion and extension of the lower limbs in degrees and sends the data to a database for analysis by the physiotherapist. The second module consists of the design of support for a telephone integrated to the crutch, to facilitate the integration with existing applications, also containing an embedded system for integration with the first module. When the patient is already on crutches, the cell phone and an embedded system coupled to the patient are used, which send signals in case the patient falls. The results are still partial and from isolated parts of the project, so that, after the completion of the modules, it will be possible to integrate and quantitatively analyze the results. The voltage source showed a current output that was maintained despite the load and without a voltage drop. The movement monitoring system through the camera recognized the knee flexion movement. The initial architecture of the system managed to include a system involving computer graphics, and screens that concern the human-computer interface. The crutch and the telephone support underwent usability tests that proved basic mechanical resistance to not present elementary difficulties in sustaining a person and a cellular device.

Keywords: Rehabilitation. Assistive Technology. Crutch. Gait.

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Estratégia inicial de uma tecnologia assistiva para reabilitação e acompanhamento de pacientes idosos

RESUMO

Este artigo apresenta uma estratégia de tecnologia assistiva para reabilitação e acompanhamento de pacientes idosos para impedir a sua queda e fratura. O foco consiste na recuperação muscular dos membros inferiores, desde uma condição de baixa estabilidade da marcha até o abandono das muletas. O primeiro módulo (módulo de recuperação) realiza a medição em graus da flexão e extensão de membros inferiores e envia os dados para um banco de dados para análise pelo fisioterapeuta. O segundo módulo consiste no projeto de um suporte para telefone integrado à muleta, para facilitar a integração com aplicativos existentes, contendo um sistema embarcado para integração com o primeiro módulo. Quando o paciente já está de muleta, são utilizados o celular e um sistema embarcado acoplado ao paciente que enviam dados em caso de queda. Os resultados são parciais e de partes isoladas do projeto e anteriores à fase de integração dos sistemas. A fonte de tensão apresentou saída de corrente adequada, o sistema de acompanhamento de movimentos através da câmera reconheceu corretamente movimentos de flexão de joelho. A arquitetura inicial do sistema incluiu o sistema envolvendo computação gráfica e as telas que dizem respeito à interface humano-computador. A muleta e o suporte para telefone passaram por testes de usabilidade que comprovaram resistência mecânica básica para suportarem o peso de uma pessoa.

Palavras-chave: *Reabilitação. Tecnologia Assistiva. Muleta. Marcha.*

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1. INTRODUCTION

Human gait is the main system of locomotion, having been conserved evolutionarily and holding wide functions. Walking provides humans with the autonomy of locomotion and freedom of access to environments that would otherwise be difficult. The gait process consists of a set of mechanisms that result from a complex interaction of muscle forces, joint movements, and neural motor commands, thus forming a displacement pattern that is observed in walking and running. The human walking process is very important in everyday life, as in addition to promoting practicality and the possibility of escaping from danger, it allows the individual to collect objects and look for what is necessary for him, as well as to have access, by himself. itself, to food, to work, to leisure, to social interaction. Over time, the natural gait process can be compromised by several factors, leading to an attenuation of quality of life levels. The deterioration of human gait can occur due to several circumstances, such as brain injuries, decreased motor coordination, interruption of nerve conduction, muscle inefficiency due to myopathy, limitation or blockage of joints due to arthropathies or arthrosis, or, simply, after severe trauma. In cases of gait difficulty, several technologies are used to provide support to individuals. Through the Brazilian Censo of 2010, it was found that about 24% of the Brazilian population claims to have some degree of disability in at least one of the skills investigated (seeing, hearing, walking, or climbing stairs) (CENSO - BRASIL, 2010). In Rio Grande do Sul, around 2,549,691 people fall into this group. The significant nature of the numbers highlights the need to develop strategies to improve the living conditions of individuals included in this section.

As a current debate in an increasingly globalized world, technologies for human mobility have been considered in the design of cities and urban environments, considering universal design. The advent of portable technologies, such as smartphones, has been included in projects aimed at improving the day-to-day lives of population profiles. The purpose of technologies, in addition to allowing communication, education, and comfort, also lies in the social inclusion of individuals who, for some reason, have some mobility difficulties. Debates around ableism seek to show that people with disabilities and special needs are not inferior, with society itself responsible for producing discourses of inferiority, which are more in the symbolic sphere than in reality itself, since individuals in general have autonomy in most cases. Bill No. 8213/9 regulates quotas, and together with Law No. 13146 of July 6, 2015, are legal instruments for the inclusion of people with disabilities. In this second law, the Statute of Persons with Disabilities, individual autonomy, accessibility, and freedom are described and assumed as a State commitment. Being legitimized by this, the provision of accessibility for people with disabilities, as well as the provision of access ramps, elevators, and other technologies become necessary to guarantee the execution of laws. The present project looks to improve the capability of a patient to walk, considering that elderly people can have some musculoskeletal damage resulting from aging, exercise wear, sedentary lifestyle, and other factors that can lead to impairment of structures for human gait. The first part of the project consists of the Rehabilitation Stage, and the second part is composed of the Locomotion and Communicability Stage.

In the first stage, we developed a precise instrument to determine the angular progress of flexion and/or extension of the knee, considering that after certain surgeries, there is a reduction of angular flexion capability. The proposal is to provide the physiotherapist with a quantitative instrument to verify the patient's progress during the physiotherapy sessions. In the system, data is sent to a database. The second part is composed of a Canadian crutch improved in terms of design with support to a cellphone and a software integration of an embedded system with the crutch and the cellphone.

The objective of the work is to support a person who may have a tendency to fall and, through technology, not allow the person to fall and have fractures, which can be more critical in older patients. Ultimately, do not let patients with limited muscular capacity fall due to lack of support, which is a tendency with advancing age and which can be fatal. The work, however, is at an initial level and consists of gathering knowledge for a first strategy. The goal in terms of technology is to provide the patient help with video and audio call support when he is alone and wants to move around with crutches, considering his locomotion difficulties. In this sense, while the first stage serves to improve the patient's physiological condition during the physical treatment, the second stage consists of using technology so that the patient has more instruments too, being alone at home or in another environment where he has access to the internet, being able to move around more safely and if it happens to the patient during the movement exercise, the system will also notify a person. Currently, some applications help visually impaired people to orient themselves through calls in which a volunteer serves as a guide for the person through the cell phone camera.[5]

[5]Be My Eyes is an example of an application in this sense. In this article, we discuss some limits of Be My Eyes presented in a review article from 2022, and we try to propose our own technology using the camera and audio call feature, as well as other phone features, that could be an alternative. However, we also present the feasibility of using Be My Eyes for patients, as a valid strategy within the Locomotion and Communicability

The development of assistive technologies along with inclusion programs is important for the pursuit of social equity since individuals who are helped by assistive technologies can have better living conditions and social inclusion.[6] Social reparation is a responsibility of society itself, which is responsible for the development of increasingly improved technologies so that people can live with more dignity.[7]

In terms of a literature review, some studies have been developed with assistive technologies for gait and lower limbs in recent years. The review search was carried out on the Google Scholar portal based on the terms "assistive technology", "gait", "rehabilitation". According to Frank Miskelly (2001), assistive technologies for the care of elderly people in institutions and at home involves video-monitoring, remote health monitoring, electronic sensors and equipment such as fall detectors, door monitors, bed alerts, pressure mats, smoke, and heat alarms (MISKELLY, 2001).

Iancu and B. Iancu (2020) reviewed the development of mobile assistive technologies for elderly people. They mentioned the following article: Wilinson and Gandhi (2015), which analyzed 50 scientific articles. They defined what they called the four most important user-centered principles in technology design: i) user experience as a sum composed of user

nucleus of this article, which can contribute to the Rehabilitation stage, since part of the rehabilitation of an elderly patient takes place when he is alone, from discipline to treatment. In this sense, the cell phone and the applications can be an instrument for welcoming the elderly and for social inclusion in a network. Technology should serve to boost this individual's quality of life, but, on the other hand, it cannot be considered the only relevant factor, since pathological conditions are complex and involve multidisciplinary teams, and also concern the social context, professional and deeper family in which the individual is inserted. The software technologies used in the article are documented in a repository on github and are open-source so that the developer community has access and can propose improvements to the codes, as well as make free use for other research and projects.

[6]According to Hernigou (2014), the first crutches date back five thousand years, being initially made of simpler materials, such as tree branches, which gradually became more sophisticated. With the change of materials, they maintained their profile of one bar or two bars in parallel. In the most recent era, of software, little by little electronic crutches or with embedded technologies emerged. The specific term to describe the electronic technology intended to be included in a double or single bar crutch in this article is called “assistive technology”. It is considered relevant to define the term. It comes from the English Assistive Technology (AT), and was created in 1988 to present different terminologies as synonyms, such as “Assistive Technologies”, “Adaptive Technologies” and “Adaptations” (SARTORETTO; BERSCH, 2014). Assistive technologies contribute to the inclusion of people with disabilities by making them independent by expanding their functional abilities. The definition of assistive technology in Brazil encompasses products, resources, methodologies, strategies, practices and services that aim to promote functionality, related to the activity and participation of people with disabilities, disabilities or reduced mobility, in favor of their autonomy, independence, quality of life and inclusion (CAT-BRASIL, 2009, p. 9).

[7]Assistive technologies usually are built by people who are next the reality of the person with a specific disability, without the participation of the beneficiaries in a significant way, which ends up leading to equipment that does not suit the needs or interests of the users themselves. In this article, we present a project that started from discussions with a group of undergraduate students. However, although the presented project is quite interesting and has a certain social value, it was not built from the beginning with the participation of a potential end user. This is, therefore, a gap in the investigation. However, an effort will be made to present positive points that reinforce the value of the project in constructive terms within the scope of the techniques used.

perception (the user's ideas on how interaction with the device is likely to occur based on the product design), user engagement (physical interaction, social interaction and activities in terms of entertainment and leisure) and user acceptability (understanding the user's physical and psychological needs and design accordingly). ii) second principle stresses the need for physical (enhancing the abilities to perform daily tasks), emotional (well-designed mobility aids can increase the feeling of safety and can increase personal independence), and cognitive (providing support for decision-making and activity reminders) support and guidance. iii) the third principle emphasizes the economic aspects: intrinsic cost (designing assistive technology for a more extensive market can help in reducing the economic barriers associated with it) and extrinsic cost (the existence of assistive technology can reduce institutional and in-home healthcare costs). iv) the social aspects refer to social connection and interaction (assistive technology can be designed to increase the social connectivity functions and to encourage physical and virtual interaction) and personal identity (a proper assistive technology design can help in re-establishing a sense of normality and comfort) (Wilkinson and Gandhi 2015).

Kittipanya-Ngam e How-Lung Eng (2009) presented a revision of tele-physiotherapy that allow patients and medical experts to carry on their sessions through telecommunication networks. Computer vision technologies can be useful in the monitoring process of the system because of the quality assessments of physiotherapy exercises. Their study shows that computer vision has some potential in enhancing and improving the telephysiotherapy system but the study of some considerations is needed before implementation. They presented a Procedure for Camera Calibration considering the Euclidean transformation between the real world and the image space for the video recorded by a pinhole camera.

Rosique Contreras, Losilla and Navarro (2021) used artificial vision to measure the joint range of motion with ROMCam, an alternative system for measuring based on estimating the human pose in 2D. The authors used artificial vision libraries and an RGB webcam-type camera. The results obtained corroborate the validity of the use of ROMCam as a low-cost, accessible tool that can even be used as a resource in telerehabilitation treatments. Contreras considered that human posture evaluation is done usually with Recurrent Neural Networks (RNNs) or Convolutional Neuronal Networks (CNNs). An alternative of low cost and high accessibility is ROMCam for the measurement of ROM. ROMCam is an application of artificial vision based on the detection of human 2D posture. It uses a library called OpenPose 2D, which used CNNs.

Hussain et al (2015) created a smart surveillance system using thing speak and Raspberry Pi. The system with Raspberry Pi worked in standalone mode without the necessity of a PC. The authors explained the characteristics of the Raspberry Pi, which is based on a system-on-a-chip (SoC) or Broadcom BCM2835 microcontroller, which includes an ARM processor. The Raspberry Pi uses an ARM processor, which can have better parallel processing capacity compared to x86 processors and with lower consumption. The IDE used was Thonny to Python 3. Thonny was chosen because it is a simple IDE to code.

2. METHODOLOGY

The research protocol used was to mechanically develop the support, in accordance with mechanical engineering techniques, and to develop the software in accordance with good computer engineering practices, with clean code and as simple as possible. Electronic engineering knowledge regarding embedded systems was also employed, as well as the scientific methodology that is common to different types of investigations. Throughout development, the most relevant target audience for what was being developed appeared: the elderly with limited mobility. This happened after we were developing the computer vision algorithm for motion recognition.

The first stage (rehabilitation) involved work integrated with a physiotherapist, to evaluate the musculoskeletal recovery through exercises, considering factors that can have reduced the autonomy of the patient. The second part of the project involves technology to allow the patient to move inside the house with more technological support, using a camera and call function, by open apps available as Be My Eyes[8] or same using the Python codes

[8]One of the biggest challenges for people who are blind or have low vision is the potential obstacles when walking down the street. Currently, there are luminous canes for people with low vision to be able to avoid obstacles more easily in low lighting contexts. There are also canes that emit sound signals when they encounter obstacles. Both in situations of obstacles and lighting, cell phones can help. Phone support can be used seamlessly with the Be My Eyes App. This application, aimed at the blind, can be downloaded by anyone from the Apple Store. On Be My Eyes, the visually impaired user can call a person and ask that person about a situation faced by the visually impaired. An example situation happens when the user would like to configure his television, to know if it is turned on, to know if it is on HDMI-1 or HDMI-2. With Be My Eyes and other applications, the cell phone can be a form of intermediary for the person with motor or visual impairment with other people with a view to helping each other to carry out a certain action. Assistive technologies to aid blind people in Brazil were reviewed by Cunha and Santos (2022), but they focused on reading technologies. As the prototype involves audio and image, it is not in the scope of this revision. Avila, Wolf, Brock and Henze (2016) proposed an study of efficacy involving thirty blind and sighted users of the Be My Eyes App. The App proved to be strong in helping with reading texts, and was also well rated on a scale of 1 to 5 for finding objects and providing assistance. For route guidance (wayfinding) the application was evaluated negatively. Be My Eyes was found not to be useful when your hands are full. At this point of improvement, the fact that there is a coupling next to the crutch, with the possibility of rotation, can help, and the cell phone can be removed from the support when necessary. Even so proposed in this article could hinder the usability of the application. In

available and integrated to the microcontroller to allow automation of the patient in situations that he would like to start the system. The research is experimental and does not propose a commercial product. The algorithms are open for developers to improve and criticize them.

Baseline data for crutch support configuration from actual crutch models were obtained by reviewing commercial crutch standards. The phone support had its three-dimensional geometric modeling in CAD software, followed by its 3D printing and physical tests of resistance to loads with the designers. The software, developed in Python, simulates the functionalities of the Be My Eyes App, composed of two main functions, which are: the function of calling and communicating with a volunteer in addition to the function of using the cell phone camera. For this, the elderly or blind user must have a cell phone that can make calls and with a camera in perfect working order. On the other hand, the person cannot have a hearing impairment. With the commercial application, blind people can be helped by volunteers to "be their eyes" and guide them through words. With this, the volunteer can both provide information about what is visible on the camera, such as a number or visual data and can guide a path, in the case of locomotion inside a house or outside, as long as there is internet communication. This assistive technology for the inclusion of visually impaired people and elderly people with limited mobility allows for better social inclusion of these individuals through interaction with other people who can help them.

The first step of the code assumes that if the patient can use the crutch, the locomotion and communicability system is activated. If not, he uses the rehabilitation system. The first module (recovery module) measures the flexion and extension of the lower limbs in degrees and sends the data to a database for analysis by the physiotherapist. The second module consists of the design of a support for a telephone integrated to the crutch, to facilitate the integration with existing applications, containing an embedded system for integration with

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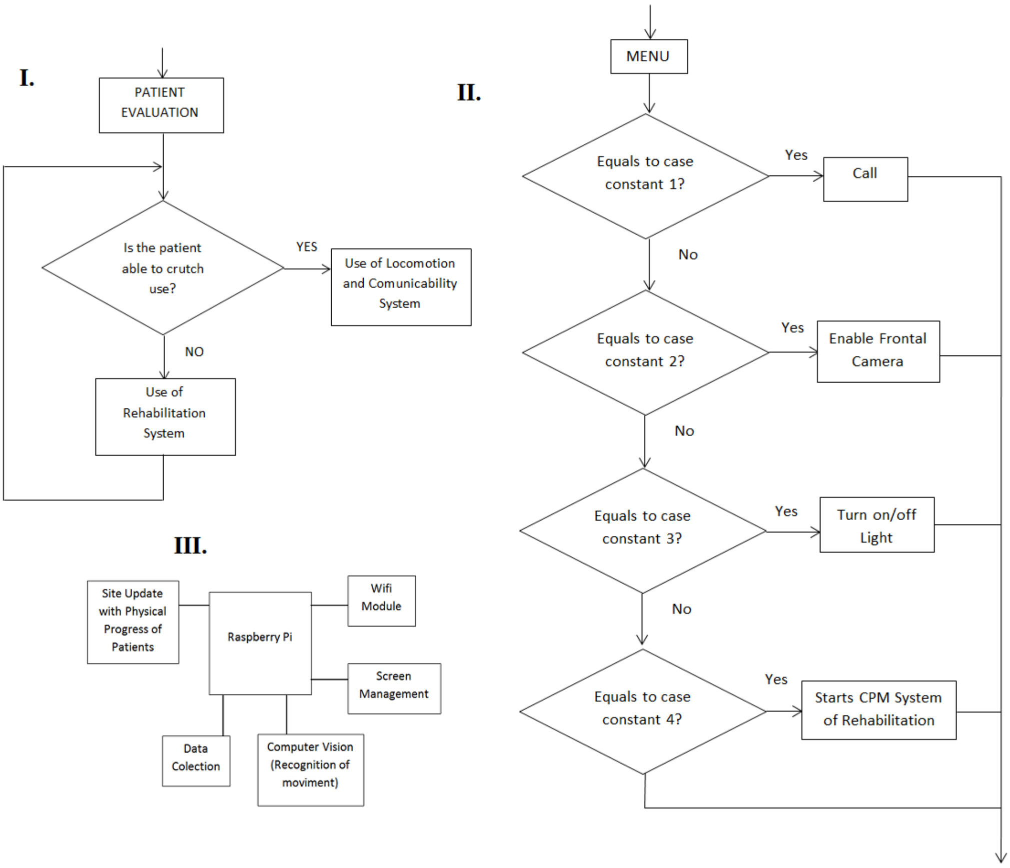
terms of usability, the fact that the cell phone is attached to the support at a certain defined height could hinder the user in handling the application's commands. As the interview with Be My Eyes users presents the perception of end users, it is possible to have an opinion from the user's side. The authors' study was not very conclusive. The authors pointed out that: “potential areas of improvement are being able to specify the type of help needed and providing training for assistants. Limited network connectivity was a serious problem. This issue is not in the hands of mobile application developers and not specific for Be My Eyes. Such problems should be kep in mind when trying to transfer results from highly controlled lab studies to the real world” (AVILA; WOLF; BROCK; HENZE, 2016, p. 2). Considering the problem of using Be My Eyes in the night, we trying to find information about Python for Android codes to turn on the LED on cellphone. The section Software to turn on the cellphone LED is showed for this reason. The purpose of this article is to present some elements to help an elderly person with low mobility and low vision to be able to move around with greater security and information using their cell phone through the Be My Eyes application adapted for this user profile. What are the characteristics of this user? What are your pains? I) Low vision; II) Low walking ability and use of crutches; III) Usability challenges: a significant portion of the elderly do not know how to deal with technologies; IV) Need for physiotherapy to maintain movement capacity and/or rehabilitation.

the first module. When the patient is already on crutches, the cell phone and an embedded system coupled to the patient are used to send data in the event of a fall. The second step of the code allows the selection and configuration of the system by a set of four options. The third step involves the embedded system in the patient and sending data. Figure 1 shows the three divisions of the code.

Figure 1: Flowchart of system evaluation and control



Source: The authors, 2023.

Axys I – Rehabilitation

Continuous Passive Motion (CPM) is used in rehabilitation after trauma or joint surgery, and its application can generate positive results in limb rehabilitation. This stage of the project aims to create a computational image analysis device that works simultaneously with the CPM to perform a more effective data collection and assist in the patient's rehabilitation. From this, we can evidence a data-driven rehabilitation and not only based on the professional's perception. The information can be integrated and provide a history of the patient. In older individuals, knee joint problems are recurrent. This joint operates on the hinge model in terms of movement and represents one of the largest and most complex joints in the human body, being under one of the highest stress loads at basal levels. When individuals need to stay in bed and undergo physiotherapy, physiotherapy is done manually by professionals or through some equipment such as the CPM (Continuous Passive Motion Apparatus) that allows programming the extension and flexion angles between -10° and 120°, which can be adjusted between these angles according to the needs of each patient. In this axis of the project, we propose an improvement of the equipment using image processing and computer vision to better manage the patient's recovery, generating a database in which the physiotherapist can have resources for the treatment.

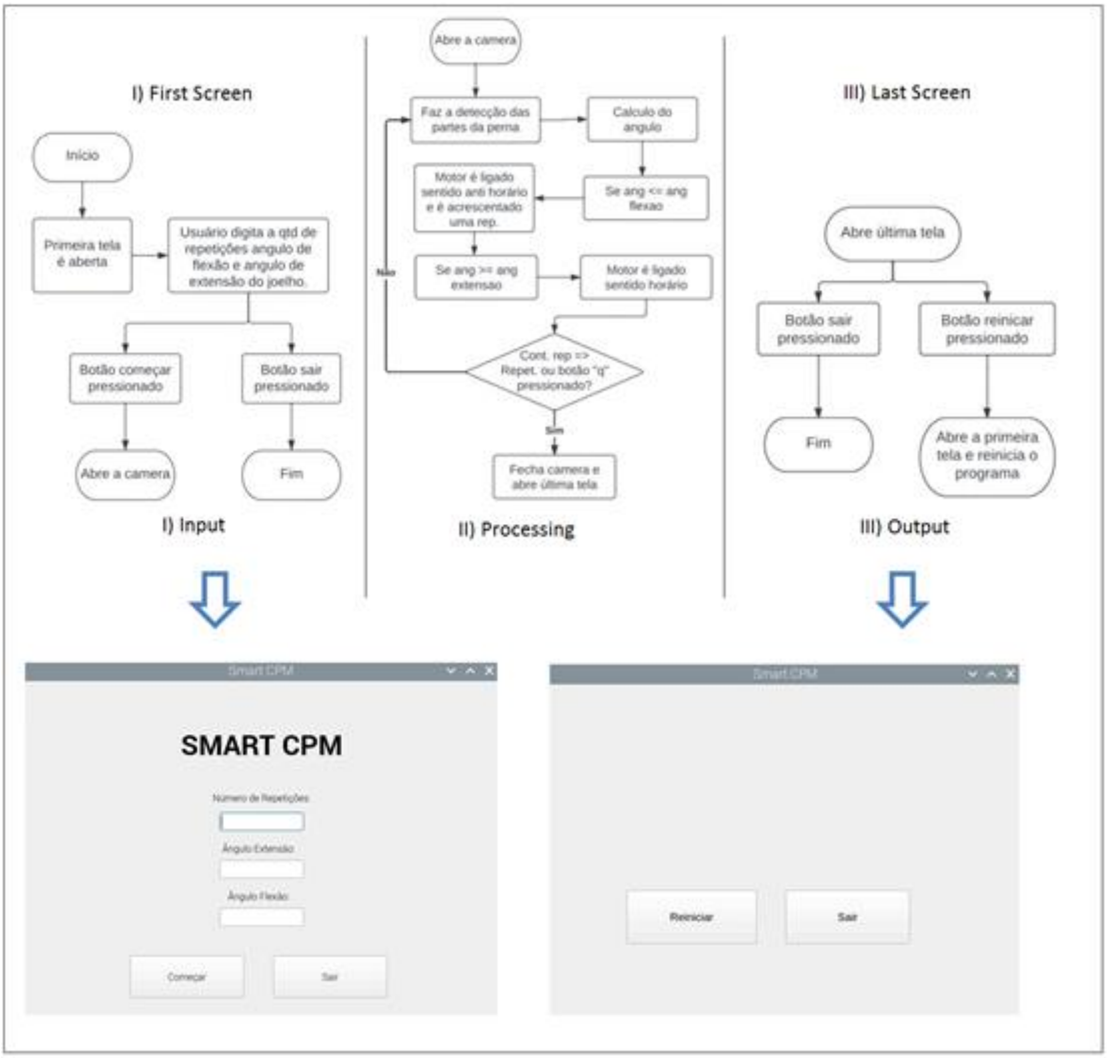
This stage involves a power supply of 24VDC, a microcontroller RaspBerry Pi 4, a webcam, an H-Bridge BTS7960, a motor of car windshield motor, and a mechanical basis to the Continuous Passive Motion (CPM). The mechanical base of the CPM was developed by engineers of the Mechanical Engineering Department and made available by Dr. Walter Fontana (Unisinos). COM basis consists of a metallic base, a rail under which the engine slides, screws, and an acrylic base, it served to flexion and extend the leg passively, that is, the engine was turned on and off with mechanical control and two limit switches. Figure 2 shows the physical structure of the CPM.

Figure 2: Continuous Passive Motion (CPM) representation

Source: The authors, 2023.

This project of Computer Vision was developed with the framework MediaPipe, which was created by Google. MediaPipe allows an introduction to fundamental problems of artificial intelligence. Used also OpenCV, PySide2, and Numpy Libraries, which are available to image analysis and object detection, facial recognition, and other functions. Raspberry Pi is very used in applications of object detection. The CPM control was developed using three stages: 1) Input; 2) Processing; 3) Output. Figure 3 shows the operational process of each stage.

Figure 3: Operational stages of rehabilitation stage of the project



Source: The authors, 2023.

The first part of the code can be found at: https://github.com/beternus/assistivetechnology/blob/main/tela1.py. The first and last screens were created using QT Designer to create a GUI screen. The program generates the code for the user by the design of the screen. Screen three code is available in a GitHub repository: https://github.com/beternus/assistivetechnology/blob/main/tela3.py. The main part of the code involves the use of several libraries, defining some points in the screen, and calculating the angle of flexion/extension. The project is able here: https://github.com/beternus/assistivetechnology/blob/main/interface.py. The code involves certain aspects of algebra, as can be seen in the attachments.

The engineers of the project developed a power supply to connect the bivolt alternating current from 110 or 220 VAC network to provide continuous current to the electronic modules of the circuit. The voltage source is made by the represented transformer, which converts the higher alternating voltage of the network to a lower value using the ratio of metallic turns. Next, there is a bridge of four rectifier diodes capable of transforming alternating current into direct current (4 x 1N4007). A filtering capacitor, placed in parallel with the rectifying diode bridge output, is responsible for filtering and attenuating the output signal, leaving it closer to a continuous signal due to the capacitor discharge time in the change of half-cycles. Finally, a voltage regulator, either with a zener diode or an integrated circuit, is responsible for setting the voltage at the working value of interest. The mains is protected by a fuse at the input in case the rehabilitation circuit is short-circuited. The choice of a voltage source with a diode bridge refers to its low cost character for powering the prototype. The choice of the Raspberry Pi microcontroller was due to the fact that it has a higher resolution than the simplest microcontrollers.

3. RESULTS AND DISCUSSION

The results of the power supply, measured with a multimeter and oscilloscope, indicated its correct operation (Figure 4).

Figure 4: Power supply of the rehabilitation project

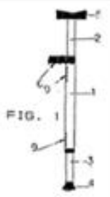
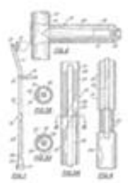
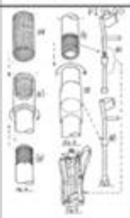
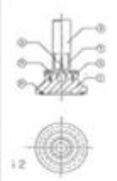
Source: The authors, 2023.

Research results in the Brazilian scenario for different types of crutches were compiled as follows. The orthosis design was divided into two categories. The first of these consisted of the category of Axillary Crutches and Canadian Crutches, in which both had different characteristics concerning comfort and stability, but had similarities in physical and mechanical properties.[9]

[9] The two scenarios mentioned are widely available in the Brazilian market. They are consolidated models due to their high functionality and anatomy. It was also verified that the models and spare parts mentioned already have a patent in the public domain. The scenario chosen is based on meeting the mechanical, functional and

Figure 5: Scenarios for the crutch

	Muleta Axilar	Muleta Axilar Regulável	Muleta Canadense Fixa	Muleta Canadense Articulada	Muleta Canadense Articulada
Produto					
Marca	Mercur	ALO	Mercur	ALO	Mercur
Preço	R$ 206,50 (par)	R$ 209,90 (par)	R$ 132,90 (par)	R$ 120 (par)	R$ 248,70 (par)
Material	Polipropileno; PVC; Alumínio; Borracha.	Polipropileno; PVC; Alumínio; Borracha.	Polipropileno; Alumínio; Borracha.	Polipropileno; Alumínio em liga especial.	Polipropileno; PVC; Alumínio; Borracha.
Resistência	Até 130 kg o par	Até 130 kg o par	Até 130 kg o par	Até 100 kg o par	Até 130 kg o par
Altura	Tam. P: 1,37m a 1,57m; Tam. M: 1,57m a 1,78m; Tam. G: 1,78m a 1,98m	Regulável em: Tam. P: 1,37m a 1,57m; Tam. M: 1,57m a 1,78m; Tam. G: 1,78m a 1,98m	Tam. Único - Altura usuário regulável: 1,45m a 1,90m.	Tam. Único de altura regulável.	Tam. Único - Altura usuário regulável: 1,50m a 1,90m.

Nome	*"Muleta Regulável"*	*"Muleta aperfeiçoada de altura regulável"*	*"Muleta canadense modular desmontável"*	*"Sapata articulada para bengala"*
Produto				
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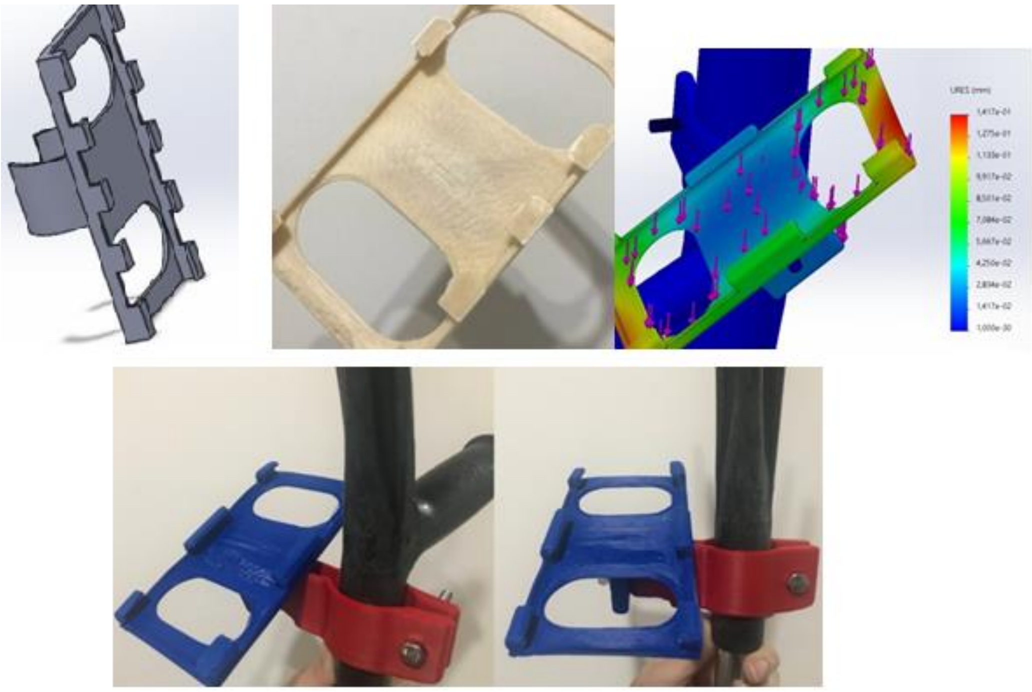
Source: The authors, 2023.

adaptability properties of the orthosis, which can be used for short to long term and also permanently, depending on the user's mobility condition. However, we understand that scenario 2 is the most promising to meet the objectives of this project, as the physical structure of the Canadian articulated crutch model offers adequate spaces in its parts for adapting the support for a mobile device, taking into account that this support will be coupled on the hand support piece at an anatomically favorable angle. Scenario 2 also had advantages over the mode of use, which occurs with a pair of crutches or just one unit of this crutch model. From there, it is possible for the user to choose to use a unit with the support and another one of his choice, given the necessary adjustments. In addition, all parts that make up the crutches, whether axillary or Canadian, and that can be replaced at some stage, must be offered as spare parts and available as close as possible to the end user, with a view to reducing costs of transportation and improving accessibility for end users and their families. In figure 5, we can check some of the patents available and the characteristics with the models relevant to the development of this project.

The device was designed in such a way that the crutch has the telephone attached to it. In case a call happens, the user would have a button to be able to start or not the conversation. The support for the mobile device should be created in an adjustable way to adapt to different types of devices, having this versatility. Below is the flowchart of one of the system's functionalities: answering phone calls with the cell phone attached to the crutch.

Some software scripts were made in Python and can be integrated with a Raspberry Pi as a microcontroller. They are software to make calls, using Twilio and existing libraries, software to activate the mobile phone camera, using also available libraries in Python. And, also, a system with a sensor to get signals of contact if the patient fall. The complete architecture was not developed yet. In terms of the construction of the physical support to attach the phone to the crutch, it was developed using CAD software, as expressed in Figure 6.

Figure 6: 3D print of the project and stress simulation



Source: The authors, 2023.

After the development of the physical prototype, some tests were carried out by the project proponents themselves, but without the use of an attached cellular device. Figure 7 expresses this step of the process.

Figure 7: Simple test performed by one of the engineers

Source: The authors, 2023.

The software of movement recognition, the basis for the rehabilitation stage, is working correctly. With the use of computer graphics combined with the CPM, it is possible to visualize and obtain data on the angles of movement, as seen in Figure 8.

Figure 8: Joint motion angular degree recognition

Source: The authors, 2023.

The equipment could be printed in 3D, so that, in the plastic constitution, it can be tested by people. However, a final project should be presented in another type of material. Within the scope of biomedical engineering, from which new technologies have been designed to provide well-being to people, the project fulfills a research role, which consists of being an investigation with social relevance, since it seeks to tackle a problem associated with technologies for human gait, a field that lacks investigative studies. As commented, the activity may consist of a base project for future works that seek to develop assisted crutches using cell phones in crutches, with the electronic integration of the crutch with the cell phones. For this, a review study should be carried out to verify what has already been developed in terms of prototypes of this nature, the limitations, and indications for better projects in light of what already exists in different contexts.

In an internet search for the terms: crutch, support, assisted, smartphone, and also their referents in the English language, we did not find solutions similar to the prototype developed, indicating that it can be used for future studies, especially concerning undergraduate studies, which involve product development and test steps. Thus, the shared prototype also has an informative character for future studies. As an example article of an assistive technology for human gait, the work can serve as a simple example study that can be transposed into other studies that involve analysis of different conditions that lead to gait alterations, which would have to be studied with more specific bibliography and more technical knowledge, but referring here to technologies for dystrophic gait or dystonic gait.

The actual stage of software development is in using Raspberry Pi to integrate some codes in Python associated with the stage of locomotion and communicability of the project. After finishing this part, it would be possible to create a system to integrate with the first part of the project. Considering that the user needs to interact with the system and that the system can collect data to optimize the response, the concepts of ubiquitous computing and pervasive computing can be useful to the construction of the technology.

Ubiquitous computing aims to make the interaction between man and computer easier, in a way that people do not realize that they are giving information to computers (COSTA, 2009). In addition, computers would have intelligent systems that would be connected or seeking connection all the time, thus becoming ubiquitous. Ubiquitous computing sought to fully integrate machine technology with human beings. (NICE-BARBOSA; HANS; BARBOSA; SACCOL, 2011). For the integration of the systems with the environment and the user, the work used some references to computing. In pervasive computing, there is a hardware part and a software part added to a native material of the object which one wants to include with a native material of the object where the pervasive computing is being inserted.

An example of pervasive computing is when a coffee maker starts to learn about the user's profile so that it can, without user intervention, make coffee for that person. The concept of pervasive computing involves devices communicating to improve the user's life and capturing information and communicating to accomplish this goal. Computers obtain information for the user's use, and can also detect other devices, such as clocks, to be a more intelligent system. However, pervasive computing systems have low mobility, are fixed, and have high embeddedness. In the concept of mobile computing, there is a wide variety of devices, such as cell phones, notebooks, and e-book readers, and the design has to be designed for one hand (one-hand design).

On the other hand, the design also needs to involve thumb design, that is, it needs to be designed in such a way that the user can work with only one hand. Still, a concern with the design would be that the physical tests would be more adequate than the emulator because, with the physical tests, the user experience (UX) can be obtained. In mobile computing, mobility is high and embeddedness is low, as they are not fixed in one place. According to Araújo (2003), ubiquity, a concept in which smart, mobile, and stationary devices coordinate with each other to provide users with access to new services, can increase human capabilities.

4. FINAL CONSIDERATIONS

Codes are being developed and shared on GitHub for free use, adaptation, and reproduction. The idea would be to develop a low-cost system that could be tested by people with the *Maker* profile who were interested in the development of assistive technologies for the elderly public. All the repository codes are available at: https://github.com/beternus/assistivetechnology. As some references point out, this type of technology can be adapted for people with limited mobility, and the possibility of integration with existing phone applications, such as Be My Eyes, can be investigated.

The voltage source showed a current output that was maintained despite the load and without a voltage drop. The movement monitoring system through the camera recognized the knee flexion movement. The initial architecture of the system managed to include a system involving computer graphics, and screens that concern the human-computer interface. The crutch and the telephone support underwent usability tests that proved basic mechanical resistance to not present elementary difficulties in sustaining a person and a cellular device.

The limitations of the article are associated with the fact that it does not yet have more substantive integrated results. However, as it was an unfunded research that involves complex steps, this article presents progress with partial results of the project. The lack of integrative results also did not allow for statistical analysis of the system's accuracy in allowing the monitoring of muscular progress and obtaining autonomy in the elderly patient in recovery. Associated challenges would be the adaptability of such a system to a patient and usability, as it would have to be an easy-to-use system. On the other hand, the great advantages of the system would be the collection of data and sending it to the database, which allowed the monitoring of health in an integrated way. The system would also have to be tested with a volunteer patient, which, if you want to stop the test, the tests are closed completely. In this sense, after finalizing the tests on the engineering team and obtaining a patient to test, it would be a good precaution to obtain at least two volunteers for the test. In addition, after completion, it would be necessary to develop a user manual and documentation for the entire project with a view to transparency and communication of its non-commercial purposes.

A future possibility is also to work with a larger number of patients to test the system. As a last point, studies to prevent falls in the elderly should not be detached from the literature on the correlation between the risk of falls and motor aptitude (BERLESE; FABER; SANFELICE; SCHAAB, 2022). Studies aimed at mitigating the risk of injury may lead to better quality of life and social inclusion indices for the elderly.

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