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Design of Smart Device for Knee Joint

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Abstract. The relationship between people and technology is growing every day, technology assistance in transportation, technological equipment in surgery, miniature models that are informing the person about their health. Using these devices often happens to be complicated especially when it comes to older ages. The purpose of this paper is to develop a prototype that will measure the load directly from the person's knee. The device will contain several sensors that will sent to the ESP32 microcontroller, the person is informed on his mobile and it is very user-friendly. The device is built on the analysis of modeling by engineering software and has been implemented in practice, it is now capable of being used in various fields such as various sports, orthopedics, in the fields of prosthetics, etc.

Keywords: IoT, Cost oriented, Health Care, ESP32.

1 Introduction

Research into prostheses to meet human needs has also pushed technological development because over the last decade there has been considerable interest from academia as well as industry in creating advanced technological solutions to improve human mobility for the lower limbs, for example for the knee [3]. The main causes of lower limb problems are divascular diseases with a statistic of 80% and as another cause is also trauma, while other smaller causes include congenital deformities, cancer, wars (especially because of landmines that mainly affect civilians after military conflicts are over) [3].

The latest technological advances have begun the implementation of chips, which make it capable of standing and mobility in accordance with the wishes of the user or person. According to the vision of prosthetics, prostheses with implemented intelligence will be able to react according to the needs of people who will enable people with disabilities to perform almost natural activities, such as walking, running, descending and climbing stairs, cycling and even for swimming and diving [12].

2 Problem Statement

The aim is to design a simple elastic device which will also contain simple and inexpensive electronic components that will be able to inform the user of his knee about the circumstances that will occur.

A device will be designed which will be able to be used by people who have problems with the knees, the device will be easy to wear and also easy to remove from the body or from his knee. The device will be identified as a 'smart' device because in its structure will be placed electronic components that can control the condition of the person, depending on whether the person is on the move in the sense that he is able to walk or run, the device will enable its monitoring at all times and as a result the device is more efficient in energy consumption.

In some cases, monitoring devices have a cost that is sometimes impossible for people to afford, the system is designed to be affordable and above all read values directly from sensors which are located in the structure of the elastic prosthesis.

Another useful feature is the results of the activities of the persons are obtained which are transferred to the mobile application of the persons who are using the device, the device that enables this function is the ESP32 microcontroller, where on its board is integrated the Wi-Fi module and Bluetooth, which allows through these modules to inform the person about the condition of his knee. The application that enables the receipt of this information is also easy to use and enables in real time to see the state of the knee load during walking, running or even other activities.

3 Literature review

Smart devices or 'smart prostheses' are those types of prostheses that contain electrically impacted electronic devices, in the most appropriate sense it means if the person is at rest, the prosthesis will be passive which made us we understand that the device is not working. Whereas if the person starts to have activity, the prosthesis will start its functioning, will start collecting data from the sensors and according to the algorithm will produce results that will inform the person about the load on his knee. The prosthesis will not be able to restore the movements of the person with limb problems but will be able to analyze the movements and loads of the knee during sitting, lifting, walking, running and how while engaging in any sports activities [12].
The latest technological advances have begun the implementation of chips, which make it capable of standing and mobility in accordance with the wishes of the user or person. According to the vision of prosthetics, prostheses with implemented intelligence will be able to react according to the need of persons who will enable persons with disabilities to perform almost natural activities, such as walking, running, descending and climbing stairs, cycling and even for swimming and diving. [12].

3.1. State of the Art

The paper ‘Active above-knee prosthesis’[12] presents the problems they will solve, the methods they have used to solve those problems with the mechanical part as well as the application of electronic devices in their built prosthesis. Initially, a person was analyzed while walking, climbing stairs and descending, by some high-cost sensors, while as a control device was used the computer and software that enabled the reading of their values. Through the calculations are found the center of gravity as well as the displacement of the mass of the person while getting up from the chair, walking on horizontal paths, on sloping roads and on stairs. From the results obtained prosthesis model in CAD software, also in the software is applied an engine to analyze the support that would make to the person while moving. The end result was a motorless prosthesis designed to be used by people without lower limbs. Unlike the works mentioned above that have designed prostheses to enable the replacement of limbs of persons and only by providing physical prosthesis and not receiving constant information from the person who uses it. [12]
In the paper ‘Dynamics of Human Gait (2nd edition)’ [20] is presented the part of measurements by sensors that are located in the body of a person where the sensor data are presented on the computer as well. Measurements are made by high-cost sensors and are placed on the person's clothing during movement, the analysis of activities is done by both limbs, also not neglecting the center of gravity in the knees. Also, by monitoring the shifting of the weight during the movement from one knee to the other as well as to the two knees where the presentation of the values for the loads on the limbs are presented in graphical forms. The result in this paper was the analysis through sensors without producing any physical model that would facilitate the movement of persons during movement. In addition to the above work that presents the methods for obtaining data and presenting that data through the computer, in this paper we will receive continuous data and that data will appear on the person's mobile. [20]

4 Results

The device is already placed on the person's knee as it show Figure 1 and once programmed we will start reading data from the sensors, but the first data will be taken from the weight sensor FSR01CE, the values read by ESP32 for this sensor is shown in Figure 2.

The model that will be used in this test is a sensor for measuring weight. In our case we used an Ohm FSR sensor model. The Ohm FSR sensor exhibits unique dynamic resistance characteristics in relation to the number of forces or weights applied. The function or mode of operation of the sensor, generally the more force or weight is exerted on the surface of the sensor, the higher the resistance.

Figure 1: Implementation of sensors and Esp32 in the knees.

The MPU6050 is a Micro Electro-Mechanical System (MEMS) which consists of a 3-axis accelerometer and a 3-axis gyroscope inside it, as shown in Figure 2. It helps us to measure acceleration, velocity, orientation, displacement, angle changes and many other parameters related to the movement of the system or object.

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Figure 2: Reading data from sensors

Figure 2 shows the results of the two sensors, read by ESP32. The two sensors were connected, through I2C communication and separate sensor ports with the control device and we obtained these values. If we analyze that the MPU6050 sensor, which gives two signals like accelerometer and gyroscope with certain values according to the condition and position of the person while the FSR01CE sensor also gives such values. If we analyze Figure 1, we notice that the person is in a standing position because the accelerometer sensor gives values (-466) and also the weight sensor gives 97% of the load, i.e., that the person is standing, on both feet the same and weighing on both feet the same, there is no movement because the values on the gyroscope are 0, in this case it would be to the detriment of the person for reasons because it is over the knee load his.

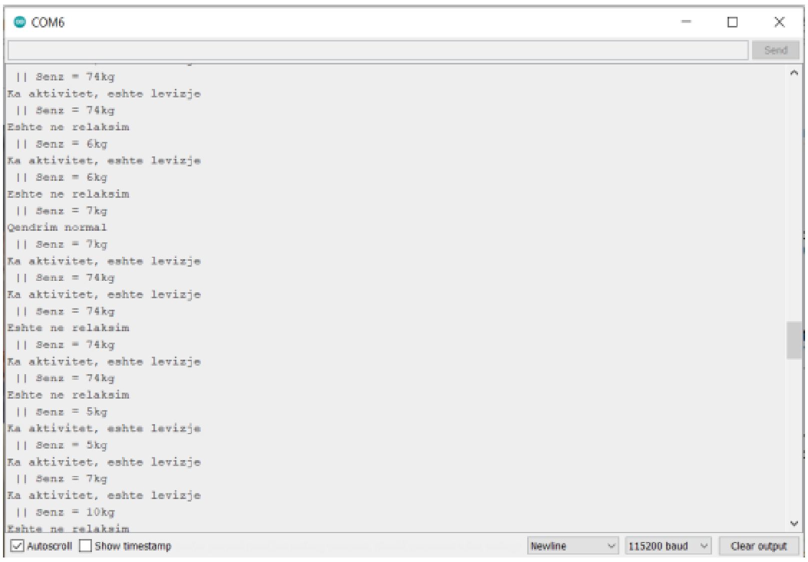

Figure 3: Creating labels according to data

Figure 3 shows a constant change in the state of human activity, as a result of which the movement of the person is found, from step to step constantly presented new values and a verbal comment to be understood by the person. When the patient moves on a flat surface or his condition is calm, the control part of the data collection shows us terms such as: ‘There is activity, it is movement’, ‘Normal posture’, ‘It is in relaxation’, etc.

- “Ka aktivitet, është lëvizje”, when the person is moving, in the sense of the activity of a sport or at least walking.
- “Është në relaksim”, as its result is that the person stays lying down and without load on the knee, that his condition may be sleep.
- “Qëndrim normal”, means that the person loads both knees with his normal weight, stands on his feet and no other position and also has no activity.

All these results are analyzed and different values of the sensor with measuring and changing the angle as well as by the sensor for measuring the weight. From these results we can conclude for patient's condition.

From different algorithms it is possible to check the condition of the person for problems from walking or load control on his knee, to inform the patient will be done by the application to be downloaded, the necessary application on the mobile, which can be downloaded free from stores offered by the application manufacturer and is called 'Blynk' is a new application that provides the ability to transmit information, which information can be in integer, string or decimal variables, etc. It receives this information from the control device in our case is ESP32 through this new application provides the ability to transfer values that are read directly from the sensors and transmitted to the patient's mobile. Broadcasting can take two forms, such as Wi-Fi and Bluetooth.

Figure 4: Display of data on mobile, such as "No load on limbs"

Figure 4 shows the patient's state when at rest, these triangular signals represent the weight load being carried over the knee or more precisely the patient's weight over the weight sensor, in which the results are obtained directly. In the load graph there have also been signals for load, now it is implied that the patient may have had movement and so far, remains in a state of calm without causing load on his knee.

Figure 5: Display of data on mobile, such as "It is on foot but not moving"

In this position the patient is standing upright or standing upright. In the graph module is presented the knee load, the signals presented as triangular shapes and not as constant signals, stands because of the delays in the transmission of information through the waves of Wi-Fi. If the patient would stay for a long time in normal posture as well as in the graph, we would see these types of signals. The history of his condition can be seen in the graph by pressing from the format ‘6h or 1w etc.’

Figure 6: Display of data on mobile, such as "It's moving"

According to this Figure 6, the shape of the patient's movement is presented. When the patient is walking, running or cycling we would get these types of signals in triangular and frequent shapes as well, this is because there is rapid activity for the patient if he is in good health but if the patient is not in such good condition, also produces results that are useful both for his personal needs and also for the health personnel who are responsible for controlling the patient's condition.

5 Conclusion

Initially, we can conclude that the overall implementation of the project was successful. The system implemented in practice turned out to be functional taking into account the problems electronic components, testing the device physically, transferring data to mobile. As we know we have three problems that we intend to address in this paper. Of course, the purpose in this application was to build a smart device that enables the analysis of his condition by the form of loading his knee, but with today's technological developments enabled us to make this device possible to be functional for people who are necessary for the use of this device and those who are interested in its operation.

The device is not able to return all the movement of the person but informs him about the load of his knee and that information will be able to be displayed on his mobile through the Blynk app. The device can be upgraded with the most advanced and modern sensors, which are permissible to be used in medicine, which made us get results with higher reliability.

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