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System implementation for gait gratification for analysis with a low-cost development board and a real-time application

Implementación de sistema para gratificación de la marcha para análisis con una placa de desarrollo de bajo costo y una aplicación en tiempo real

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Abstract

Gait analysis is important to detect abnormal patterns caused by disease or injury in human body parts such legs, ankles, arms, elbows, back, and hips. Suitable treatments and routines can be established from this analysis, and it is possible to determine what may be appropriate for each patient according to the walking pattern and body movements presented by them. In this project, a wearable system with accelerometers and low-cost effective development board is implemented, which can be a practical tool for health professionals for measuring spatiotemporal gait characteristics and assign a proper treatment. Finally, it can be concluded that the system presented has a reliable performance.

Spatiotemporal analysis, Gait, Sensor technology, Accelerometer, Wearable sensors

Resumen

El análisis de la marcha es importante para detectar patrones anormales causados por enfermedades o lesiones en partes del cuerpo como piernas, tobillos, brazos, codos, espalda y cadera. A partir de este análisis se pueden establecer tratamientos y rutinas adecuadas, así como determinar cuál puede ser la más acorde para cada paciente según el patrón de marcha y movimientos corporales que presenta. En este trabajo se implementa un sistema portátil con acelerómetros y una placa de desarrollo de bajo costo, que puede ser una herramienta práctica para que los profesionales de la salud midan las características espaciotemporales de la marcha y asigne un tratamiento adecuado. Finalmente se puede concluir que el sistema presentado tiene un desempeño confiable.

Análisis espacio temporal, Marcha humana, Tecnología de sensores, Acelerómetro, Sensores portátiles

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Introduction

Gait analysis is an important activity to observe human motion to find abnormalities in locomotion. Wearable systems using accelerometers are a common practice to perform these tests. However, sometimes the main electronic board to integrate the entire system is expensive; they need to have some features to obtain advantages of the portability. Nowadays, these implementation boards must have wireless communication, handling capacity for several tasks, communication for several devices and the most important goal, low power consumption.

There have been several alternatives for gait studies as described by Zani 2022. On one side, the image processing systems, and on the other hand the accelerometer sensor systems. Starting with image processing, these gadgets demand bigger spaces and budget, depending on the human disclaimants required to be measured. Contrary to accelerometer sensor wearable systems, which tend to be smaller and suitable for tasks where these tests must be performed in sport, training session and physical activities.

There have been several accelerometer sensor systems such Vertens 2015, Cardou 2008, Cardou 2009, Tao 2012, Muro-de-la-Herran 2014, Kavanagh 2005 and Fourati 2011. In these works, there have been other uses for the gait measurement, a different approach. Nevertheless, some other works using wearable systems were presented by Liu 2009, Donath 2016, Kluge 2017, Mayagoitia 2002, and Verheul 2019. Finally, there are published thesis such as Adkins 2023 and Chanda 2023, where gait systems took place for treatment design and patient treatment with a motion disorder.

Wearable System

The main goal is to build a reliable tool to accomplish a human gait study at low-cost. Therefore, a fast development board which reduces implementation time, because sensors and the board are pin-connected, makes its construction easier. The system is formed by an ESP32-WROOM-32, five AXL345 accelerometer sensors with SPI communication, a DS3231 RTC to set the time and day of each test, a microSD memory module to save a data backup when wireless communication fails and a battery for power supply. System components and their connections are shown in picture 1.

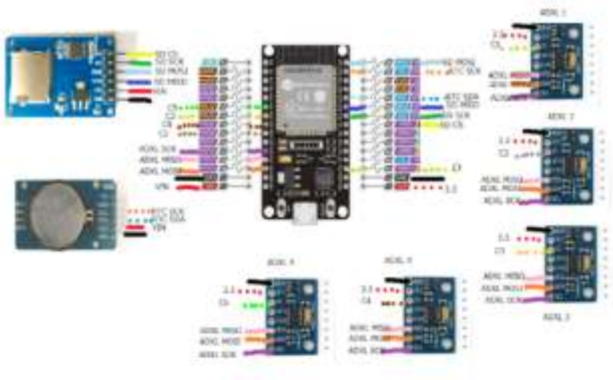


Figure 1 System elements and pin-connections

In this section, the way the system works is explained. First, The ESP32-WROOM-32 is turned on, and as soon as it happens the sensors and microSD memory are initialized reading their direction by the SPI protocol. Secondly, an IP direction file, previously loaded, with the name and password of the Wi-Fi network is read by the ESP32-WROOM-32, and Wi-Fi communication starts. Then, the board initializes working as a server with an HTML webpage, where data will be shown. Finally, I2C is only used by the RTC, so there is no problem to communicate with the ESP32 board. It must be mentioned that the ESP32 pin-port must be set as SPIMODE3 linked to the 1 MHz SPI Clock. Now, SD serial communication is set to 115200 bauds.

The index file loaded on the microSD is taken by the Wi-Fi module (ESP32), with the HTML code is executed so real-time interface begins to plot the signals of the accelerometer sensors. Since the board code is asynchronous to the sensor date collecting, the embedded server on the chip demands data update of every sensor every 200ms to show the data graphic at all time.

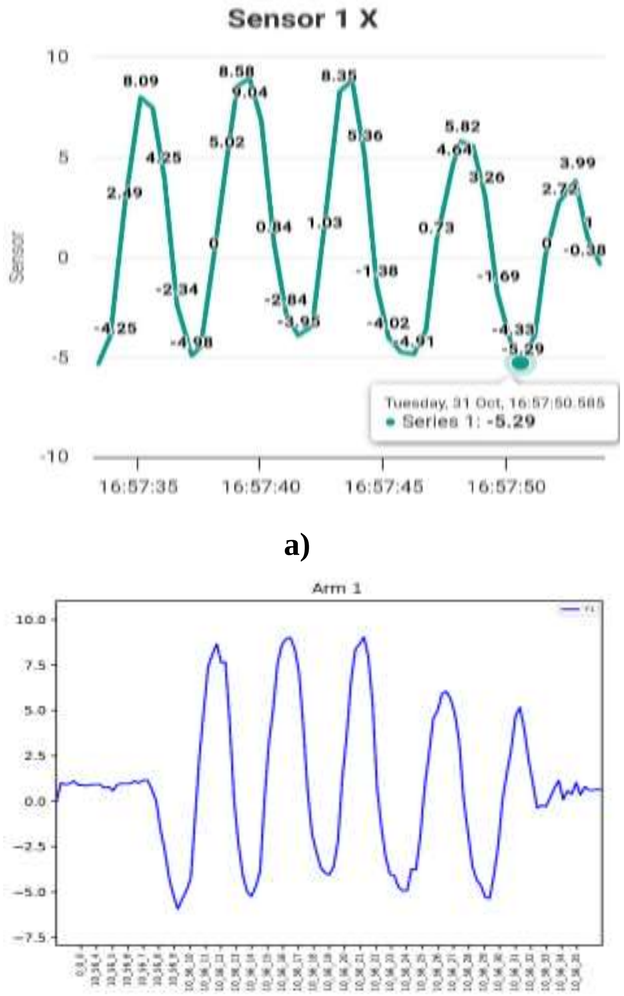
During main code execution, a loop is performed, which calls a function to read all the 5 sensors one by one. Information for each axis is saved into a two bytes variable, so the tree axis information is saved into a six-space array (two for each axis). Then, a shift is done to obtain the complete data of each axis in form of a three-space array. An RTC update is asked by the code to have the date, hour, minute and second of the sensors reading. Information is turned to a string and then concatenated to the sensor value, to be stored in the SD card. As mentioned before, this action is performed every 200 mS.

System tests

Tests took place on a regular person with no locomotion problem at that moment. However, there is an agreement with another educational nursing program, where there are physical rehabilitation classes, and professional practices with real patients' participation.

Results

On this section, graphics of arms and legs movement measures are presented. There is a comparison between the data in the real time application on the website and the date stored on the microSD, as shown in graph 1, where right arm graphics are compared. On the next figures, comparisons are shown between raw data coming from the server and graphed on the wireless application; and the graphic obtained using an off-line Python-based data processing script, from the data collected in the microSD during a preformed test.

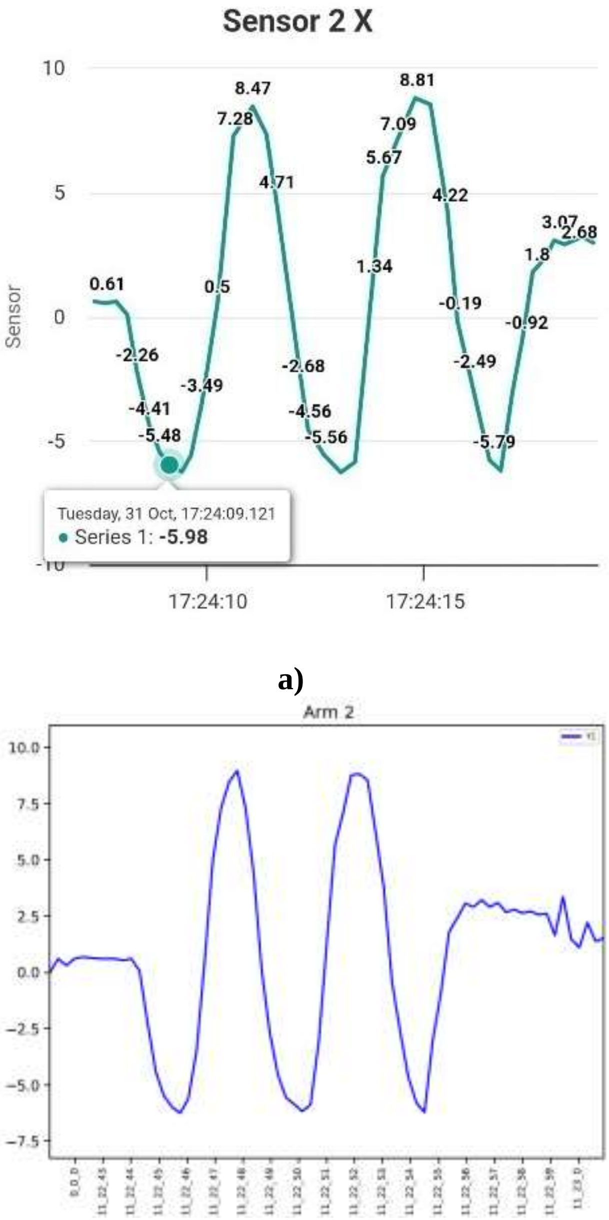


a)

b)

Graph 1 a) Real-time application graphic shown on the website (right arm) vs b) Data storage in the microSD module graphed with Python

In the next figure, the graphics of the left arm are presented as well. The same comparison is done between the real time application on the website and the data written on the microSD, as shown in graph 2 (left arm).

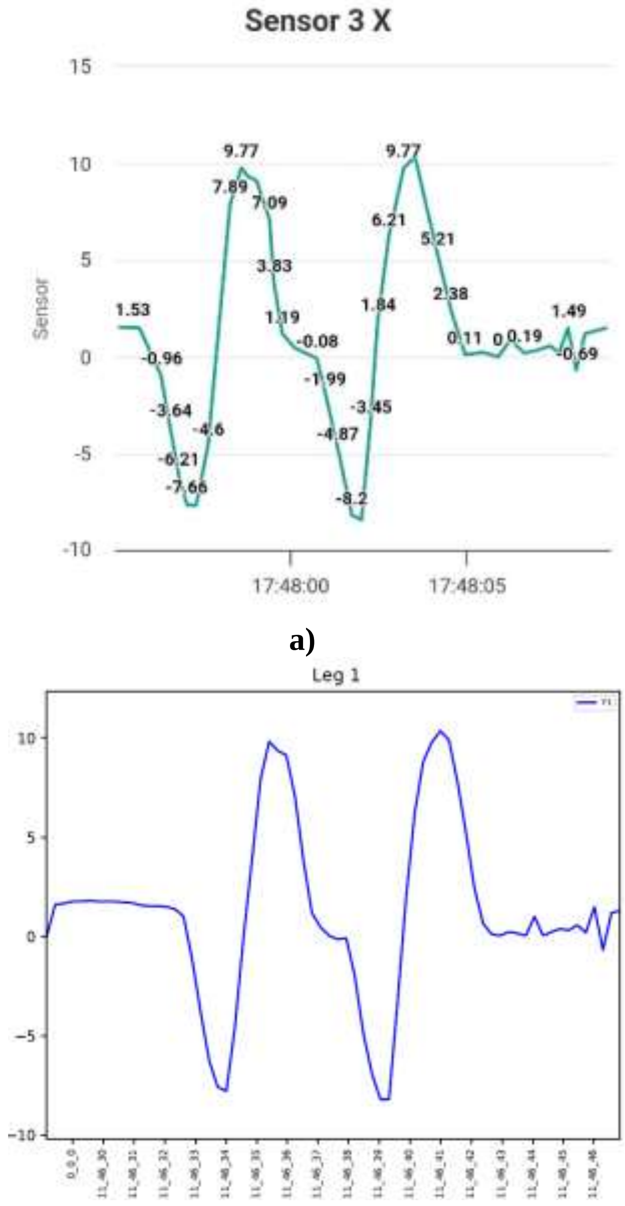


a)

b)

Graph 2 a) Real-time application graphic shown on the website (left arm) Vs b) Data storage in the microSD module

Now, leg graphics are presented. In the Graph 3, the right leg is tested, also comparing the real-time graphic and the one obtained from the Python interface.

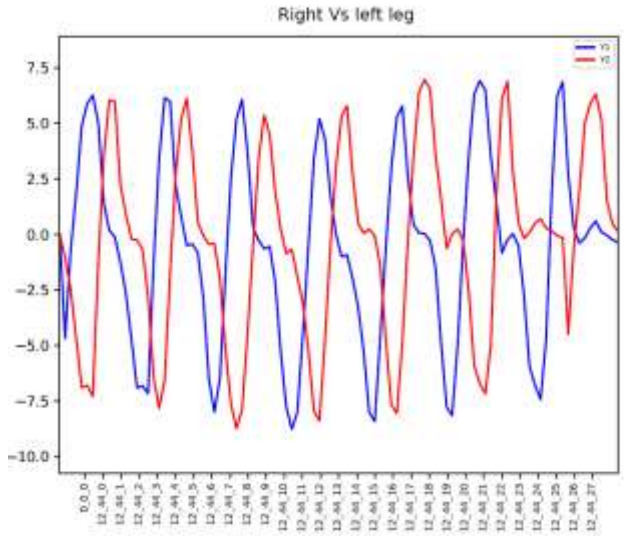


a)

b)

Graph 3 a) Real-time application graphic shown on the website (right leg) Vs b) Data storage in the microSD module

Finally, it is necessary to show both legs in Graph 4, walking at the same time, presenting a diphase with every step the subject person has performed.



Graph 4 Right leg and left leg are moving with a diphase between both movements

Conclusions

The data and graphics presented in this work show the system results for a test done on a person gait walking, on a plane surface area and collecting the data to be plotted after the tests. Moreover, the design time for this diagnostic tool was about three months, where the hardest part was the main script coding stage, because implementation, connections and test were short-time covered.

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