SMARTCUEING

SMARTPHONE BASED CLOSED-LOOP AUDITORY CUEING SYSTEM

The purpose of this project is the development of an application capable of providing Parkinson’s Disease (PD) patients with a way to correct and enhance their walking through the use of auditory cues, using a headset connected to a smartphone.

Motivation

PD is a neurodegenerative disorder that causes physical impairment. Typically, the most evident motor related symptoms are shaking, rigidity, slowness of movement, difficulty with walking and an abnormal postural balance.

A way to reduce gait variability on People with Parkinson's (PWP) is through the use of Rhythmic Auditory Stimuli (RAS). The biggest benefits from the use of RAS are improvements in stride length, cadence and gait velocity.

Description

Data from the smartphone's accelerometer, gyroscope and magnetometer, positioned near the center of mass, are used to analyze gait and detect whenever a symptom occurs.

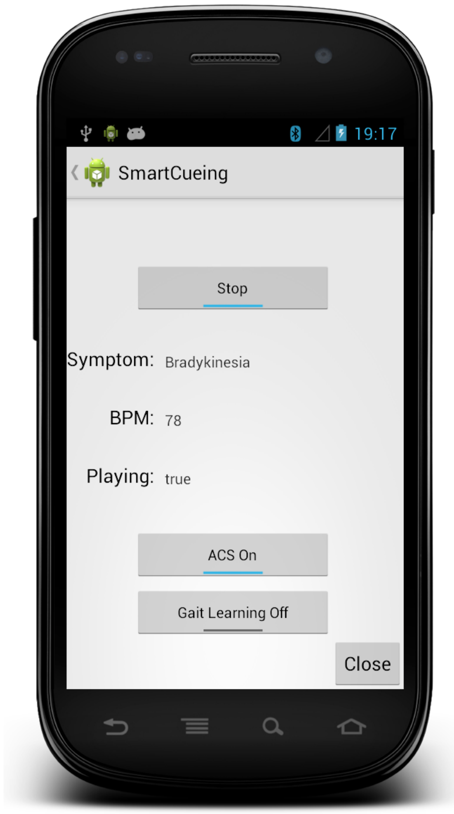

Fig1. Smartphone Based Closed-Loop Auditory Cueing System Prototype.

The sensor module is responsible for fusing sensor data in order to obtain measurements of accelerations in the vertical direction of the Earth. Patterns of vertical, mediolateral and anteroposterior accelerations produced during gait are considered to detect steps, as well as to estimate spatio-temporal gait parameters. Sensor data is also used to detect bradykinesia using a threshold-based approach in real-time.

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Features

This solution, through the incoming data from the smartphone's embedded motion and position sensors, performs a gait analysis of the PWP, estimates spatio-temporal gait parameters and uses the estimated temporal gait parameters to modulate the auditory cues played through Bluetooth headphones. RAS can be triggered automatically whenever a motor symptom is detected.

Types of RAS

- Metronome
- Sound Synthesis
- Music Synthesis

The sound module works automatically according to the information it receives from the sensor module. It can output 3 different types of RAS: a metronome, a sonification of the swing phase during walking (Sound Synthesis) and generation of algorithmic music in real-time (Music Synthesis). A pace-fixing or pace-matching mechanism can be set, where the first one uses the first calculated cadence throughout the application's run-time and the last one matches the current walking cadence of the PWP. These two modes are activated automatically, based on the symptoms detected and gait parameters. A gait learning mode can also be set, where RAS with an adequate rhythm is always playing, even if bradykinesia is not detected.

Tests

The tests were performed in two stages, the first one to evaluate the detection of gait parameters and the identification of symptoms and the second one to evaluate the performance of the sound module.

10 PWP, with a mean age of 64.1 ± 8.33 and 6 of them usually have bradykinesia, were asked to walk with and without RAS. Gait parameters and symptoms were annotated manually to compare with those detected by the smartphone. A total of 66 minutes walking was collected from the smartphone's embedded sensors and then analyzed.

Results

The step detector had a mean absolute percentage error of 1.85% and the step length estimator, when calibrated, had a mean absolute percentage error of 5.26%.

More tests are necessary in order to evaluate the detection of bradykinesia due to the fact that only two PWP suffered from this symptom during the tests.

Further analysis is required to properly evaluate the sound module, but the PWP, and their accompanying physiotherapists, reported that the RAS that improved their walking the most was the metronome and the sound synthesis.

Future Work

As for future work, this project should investigate further the effect of the different types of RAS on the PWP. Also, to include a bigger range of PWP, it is necessary to expand the system so that other symptoms can be detected.

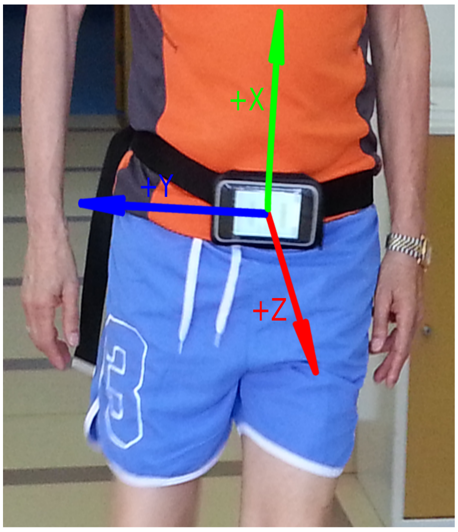

Fig2. Smartphone positioning and coordinate system considered for the analysis of gait.