

Design of an assistive device to detect freezing episodes and provide audio/vibratory cues to avoid falls

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Abstract

This paper primarily discusses the Freezing of Gait which is a type of gait abnormality and generally occurs in Parkinson Disease patients which cause an interruption to their life. During a FOG episode, the subject is rendered unable to continue moving or even manoeuvre. These episodes give rise to the danger of the patient landing on the ground and often renders a person immobile. The aim of this device is to develop a technique to identify the effect of 'Freezing of Gait' in people suffering from Parkinsons Disease and to provide feedback on detection and improving self-efficiency in about their daily life.

1. Introduction

Parkinson's Disease has been known to mankind as one of the most typical neurodegenerative health issue and almost over 9 million individuals are affected all over the world. This can lead to abnormality in a person's locomotion. Patients suffering from this chronic illness is reportedly been diagnosed with disabilities while walking, standing up and even while moving through a turn. Some people seem to show a peculiar phenomenon known as the Freezing of Gait. During such a condition, the person feels the sensation of his feet glued to the ground(while trying to walk), or he himself is stuck to his chair(while trying to stand up). In such a situation, he is unable to use his dominant feet to take a strand forward or just stand. Often their legs shake vigorously and they end up landing on the ground. This particular phenomenon is seen in those patients who are still in the rehabilitation category of the treatment. Countless doctors and physiotherapists are trying and have devised various ways to tackle this situation. Some of them include- humming to a beat while walking, following a particular pattern on the ground and so on. While these treatment goes a long way, it still makes that patient dependent on a person to look after them. So if a device is made to work and assist the patient in such regards, then this would make him more independent. The manifestation of Parkinson disease in Southern Indian population having a prevalence rate as high as 3,932 among the middle-aged men who are over 40 years of age and the elderly men adults over 60 years of age having the prevalence rate of 5,012 per 100,000 population[1] Indians have lower rate of occurrence compared with Caucasian populations. [2-4] Freezing of Gait is a highly debilitating, poorly understood manifestation of Parkinson's disease (PD) that severely limits patients' mobility. When coupled with postural instability in PD patients, FOG is a common cause of falls, complications of which can occasionally lead to death.[5]

2. Materials and methods

In the following section, we explain the peripherals required for the designing of an aiding device and how it is used to recognize the onset of FOG.

Sensor

The sensors used in the designing of the device consists of MPU-6050, comprising of an integrated 6-axis Motion Tracking device which includes 3-axis gyroscope, 3-axis accelerometer and a Digital Motion Processor (DMP) all in a small package of 4x4x0.9mm package. The MPU-6050 features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs and three 16-bit ADCs for digitizing the accelerometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope full-scale range of ± 250 , ± 500 , ± 1000 , and $\pm 2000^\circ/\text{sec}$ (dps) and a user-programmable accelerometer full-scale range of $\pm 2g$, $\pm 4g$, $\pm 8g$, and $\pm 16g$. [6] Communication that is carried by all the registers in the form of I²C serial interface and has a separate VLOGIC reference pin. [6] This also features a Gyroscope which enables the device to detect the position of the patient. The following Gyroscope has a Digital-output X-, Y-, and Z-Axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ± 250 , ± 500 , ± 1000 , and $\pm 2000^\circ/\text{sec}$. One key feature which includes the improved low-frequency noise performance and Digitally-programmable low-pass filter. The operating current for the Gyroscope is 3.6mA which meets according to our requirements. [6]

Vibration motor

A sensory cue is furnished to the patient while experiencing FOG episodes with the help of a coreless DC motor. The ERM is a compact DC motor with an operating voltage of 3V. The wires

along with the magnetic field is arranged in a way which produces torque along the rotor axis. The stator interacts with armature to create motion. The armature is a collection of thin metal plates stacked together and wound around with wires. The coils once energized produce magnetic field causing rotation and displacement. This continuous motion of displacement is perceived as vibration. [7]

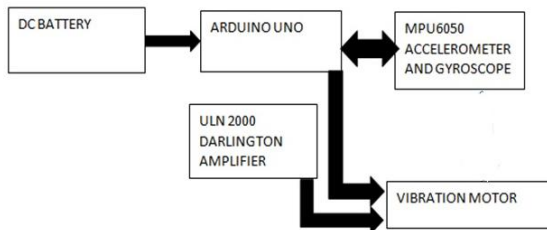


Fig. 1: Block diagram of the assistive device

Block diagram

This block diagram of the model gives a brief description of the working of the device. The Arduino Uno is being powered with a DC 9V battery which gives better supply to the controller. A ULN2000 series darlington pair transistor is used to supply power to the vibration motor as the power from the Arduino Uno is insufficient to run the motor.

The Arduino sends and receives signals to and from the MPU6050 which shares its information about all the three axis with the Arduino and the vibration motor followed by lighting of an LED and the sound made by buzzer.

ULN2000 series motor driver

The vibration motor would be run from signals from the Arduino Uno, but digital o/p pins of the Arduino are not enough to provide enough voltage required for running the vibration motor hence the DC motor is run with the help of a ULN2000 series motor driver which has the details as follows. ULN2003 belongs to the family of ULN200X series of ICs. ULN2003 is a high voltage and high current Darlington array IC. It consists of seven NPN Darlington pairs that features high-voltage outputs with common-cathode clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500mA. The inputs and outputs are provided opposite to each other in the pin layout. Each driver also contains a suppression diode to dissipate voltage spikes while driving inductive loads. [8]

3. Data analysis

The statistic was collected from various healthy people. We asked them to stand, walk (shuffling motion), and vibrate their feet to mimic the episode of situation of freezing. The data that we gathered was that of the coordinates of the x-axis, y-axis and z-axis of the accelerometer and the gyro sensor. The values were recorded on an excel sheet. Next, we took the data of all individual that was recorded before and sorted them in the sequence of standing, shuffling and vibration values. We repeated the Then we made graphs for all these healthy subjects. This was done to identify the freezing episode and how its attributes are different from that of the other motion performed by the volunteers.

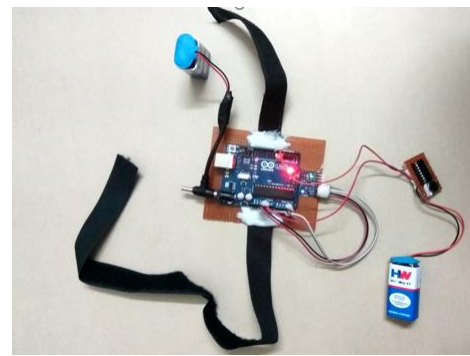


Fig. 2: The actual working device

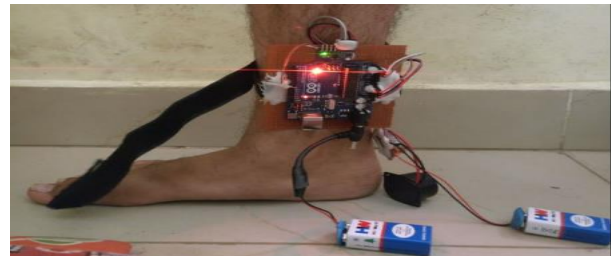


Fig. 3: The device while strapped onto the patient legs

After this was done, we took on the next task, which was to decide a threshold value for the accelerometer and the gyro sensor. This time we took accelerometer & gyro sensor value for vibration of every individual and plotted a graph. This way we could find the maximum and minimum values of the x, y and z axis for every subject. After this we took the mean of all the maximum values and set it as one of our threshold for all those axis and performed the exact thing for the minimum values. This way we were able to define the threshold for which the vibration motor would answer to the metamorphose in the orientation of the device. These values were carefully examined to realize if they interfered with the normal locomotion of the person. This way we established a proper set of values for our device.

4. Results

Graphs

After collection of the required data on the patients the data was recorded and further the graphs were plotted depicting the freezing of gait.

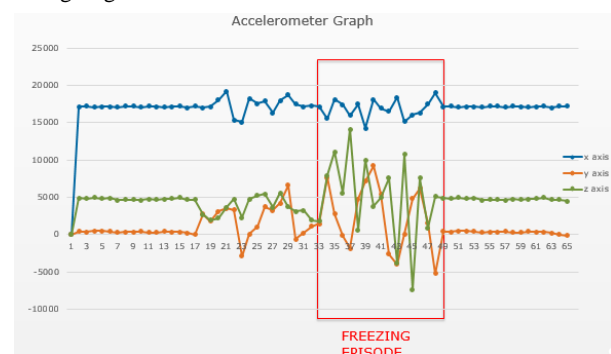


Fig. 4: The graph obtained while taking the accelerometer readings obtained from the MPU 6050

The above graph depicts the accelerometer reading over the entire cycle of standing, walking and shuffling respectively. The blue line projects the x-axis which is along the direction of the ankles. The orange line projecting the y-axis which is the direction of walking and also the blue axis showing the z-axis which is the vertical movement of the leg in an upward and downward motion. The first straight line in all the axis corresponds to the subject standing without creating any subsequent movement. It is then

followed by way the usual walking pattern which can be seen by certain fluctuation in the graph. After this there is a massive disturbance in the signal, which corresponds to the shuffling of legs which occurs instantaneously at any interval of time. This shuffling signal depicts the Freezing episodes as observed by the marked rectangle in the graph which occurs for an interval for 3-5 sec at which instance the Buzzer, LED light and the vibration sensor starts accordingly when the change of values are measured. The above graph depicts the same corresponding readings obtained while taking the accelerometer readings. The green line, orange line and the blue line in the graphs displaying the x-axis, y-axis and z-axis respectively. The following tells about the change in orientation while standing which is shown by the straight line in the graph followed by the little or minor disturbances while walking which happens due to different orientation of the walking of the patient. The shuffling or the Freezing episodes are shown by the marked rectangle as shown in the figure 5.

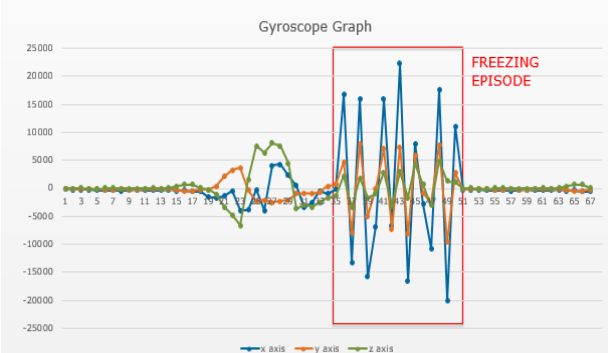


Fig. 5: The graph obtained while taking the gyroscope readings obtained from the MPU 6050

Table I: Threshold Values for the accelerometer

Axis		Values
Y-axis	Minimum	-5315
	Maximum	8390
Z-axis	Minimum	-5294
	Maximum	11653

The threshold values are calculated by taking the mean values of at least 5 patients while following the cycle of standing, walking and shuffling. While calculating we considered the values of the accelerometer specifically which provide exact detection of freezing episodes during the testing of the device along the y-axis and z-axis. As there was no significant difference (or remains constant) along the x-axis in accelerometer values while testing. Hence we neglected the values along x-axis. Hence the range of values used for detecting of freezing episodes are mentioned in the Table 1.

5. Vibration and audio

The vibration motor receives the signal from the digital output pin6 (or D6 in the diagram) from the Arduino Uno board which is connected to the IN1 (or the input 1 pin) of the ULN 2003 which further is connected to motor. Also the Buzzer is also connected in series with the motor for providing audio cues to the patient. Also an LED light is included in the system which provide a visual aid for the testing the correct working of the motor and the buzzer. When the battery is connected across the other end of buzzer which provides the power to the vibration motor.

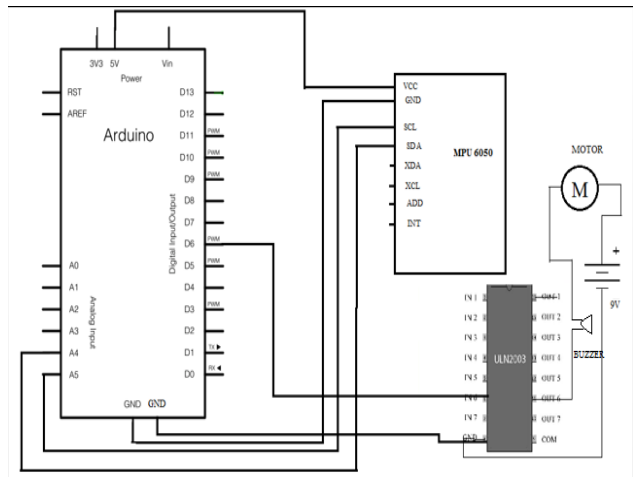


Fig. 6: Circuit Diagram

The threshold values are included upon modification in the program for the Arduino Uno. During the normal motion of the patient both the vibration motor and the buzzer will be inactive as it continuously compares the threshold value with the values given by the accelerometer. Once the threshold values matches with the values range then the signal is sent to the ULN 2000 series darling ton amplifier which further conveys the signal to the buzzer and the motor as in the circuit diagram and further sound and vibration is produced by the buzzer and the motor respectively.

6. Conclusion

The freezing episodes in a patient hinders his or her natural way of walking in Parkinson's patients. Their unnatural way pose difficulties in day to day life, hence to minimize that effect we devise this system providing necessary cues/feedback to the patient which allows them to overcome their immobile state and take a step without any need of external support.

References

- [1] Gourie-Devi M, Gururaj G, Satishchandra P & Subbakrishna DK, "Prevalence of neurological disorders in Bangalore, India: a community-based study with a comparison between urban and rural areas", *Neuroepidemiology*, Vol.23, No.6,(2004), pp.261-268.
- [2] Saha SP, Bhattacharya S, Das SK, Maity B, Roy T & Raut DK, "Epidemiological study of neurological disorders in a rural population of Eastern India", *J Indian Med Assoc*, Vol.101, (2003), pp.299-304.
- [3] Gourie-Devi M, Gururaj G, Satishchandra P & Subbakrishna DK, "Prevalence of neurological disorders in Bangalore, India: a community-based study with a comparison between urban and rural areas", *Neuroepidemiology*, Vol.23, (2004), pp.261-268.
- [4] Das SK, Biswas A, Roy T & Banerjee TK, "A random sample survey for prevalence of major neurological disorders in Kolkata", *Indian Journal of Medical Research*, Vol.124, No.2,(2006), pp.163-172.
- [5] Freezing of gait in Parkinson's disease MPanisser-Neurologic clinics, (2004).
- [6] MPU-6000 and MPU-6050 Product Specification Revision 3.4, IvenSense Inc.
- [7] Vibration motor specifications, precision microdrives.com/application-notes/ab-004-understanding-erm-vibration-motor-characteristics
- [8] ULN2000 motor driver specifications, www.datasheetcatalog.com