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Gait Activity Monitoring using Distributed Wearable Sensors for Patient Recovery

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Abstract - ***Gait analysis using wearable sensor is cheap, convenient, and efficient way of providing useful information for health related applications. It is used as a clinical tool in the rehabilitation, sport activities, and diagnosis of medical conditions. Gait analysis is used for non-automated and automated continuous monitoring improvement of patient recovery. Automated systems are important in assisting physicians for knowing the status of patient recovery. This study presents preliminary steps of designing a clinical decision support system for monitoring the improvement of patient by considering the parameters like steps taken, distance covered, and speed covered and observed angle of patient. This study compares the gait parameters of two patients by considering above parameters .The new system was built using three-axis accelerometers to automatically detect walking speed, angle of variation, steps taken per unit time, calories burnt. A progressive improvement in patient can be observed during walking and it is done through Visual Basic (VB) software.***

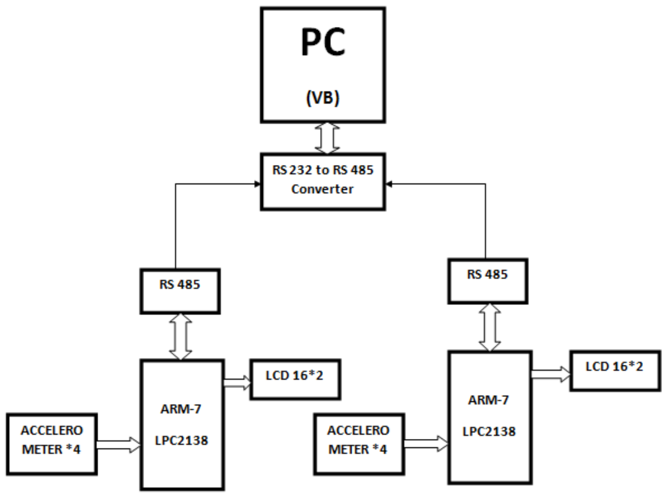
Key Words: Gait analysis, Wearable sensors, Human kinematics; Joint kinetics; Electromyography; Clinical application etc.

1. INTRODUCTION

Parkinson's disease is the second most common neurodegenerative disorder and the most common movement disorder. Efficient continuous patient monitoring is essential for Parkinson's disease. Doctors diagnose many as 60,000 new cases each year, so we need such a system which enable continuous patient monitoring.8-9% people in India suffer from Parkinson's disease. An estimated seven to 10 million people worldwide are living with Parkinson's disease. Gait analysis is effective for Parkinson's disease as it leads to continuous patient monitoring.

Gait analysis is the systematic study of human locomotion. This type of analysis involves the measurement, description, and assessment of quantities that characterize human locomotion [1]. In gait analysis using wearable sensors, motion sensors are worn or attached to various parts of the patient's body, such as the foot and waist. These sensors, which may be accelerometers, gyrosensors, force sensors, strain gauges, inclinometers, goniometers, and so on, can measure various characteristics of the human gait [2,3].The movement signal recorded by these sensors can be used to perform the gait analysis. For example, the temporal characteristics of gait are collected and estimated from body-worn accelerometers and pressure sensors inside footwear, as reported in several papers [4–8].

1.1 System Implementation



A. Microcontroller Unit

The C is the final decision making body on the system. The logic is developed and then the program is burned inside the microcontroller and the other peripherals are accessed Via microcontroller only. The ARM7TDMI-S is a general purpose 32-bit microprocessor, which offers high-performance and very low power consumption. The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of micro programmed Complex Instruction Set Computers (CISC). This simplicity results in a high instruction throughput and impressive real-time interrupt response from a small and cost-effective processorcore.Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously. Typically, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory. The ARM7TDMI-S processor also employs a unique architectural strategy known as Thumb, which makes it ideally suited to high-volume applications with memory restrictions, or applications where code density is an issue. The key idea behind Thumb is that of a super-reduced instruction set. Essentially, the ARM7TDMI-S processor has two instruction sets: The standard 32-bit ARM set. A 16-bit Thumb set. The Thumb sets 16-bit instruction length allows it to approach twice the density of standard ARM code while retaining most of the ARMs performance advantage over traditional 16-bit processor using 16-bit registers. This is possible because Thumb code operates on the same 32-bit register set as ARM code. Thumb code is able to provide up to 65.

B. Liquid Crystal Display

LCD is used in a project to visualize the output of the application. We have used 16x2 LCD which indicates 16 columns and 2 rows. So, we can write 16 characters in each line. So, total 32 characters we can display on 16x2 LCD. LCD can also used in a project to check the output of different modules interfaced with the microcontroller. Thus LCD plays a vital role in a project to see the output and to debug the system module wise in case of system failure in order to rectify the problem This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.We are using the LCD here for displaying our project name after initialization.LCD continuously shows the X,Y axis values after every 10 sec.

C. RS 232

RS 232 is a serial communication cable used in the system. Here, the RS 232 provides the serial communication between the microcontroller and the outside world such as display, PC or Mobile etc. So it is a media used to communicate between microcontroller and the PC. In our project the RS232 serves the function to transfer the edited notice (or data) from PC (VB software) to the microcontroller, for the further operation of the system.RS-232 is a standard for serial communication transmission of data. It formally defines the signals connecting between a DTE (data terminal equipment) such as a computer terminal, and a DCE (data circuit-terminating equipment such as a modem.

D. RS 485

RS 232 is well-known due to popularity of today's PC's, unlike the RS422 and RS 485. These are used in industry for control systems and data transfers (small volumes, NO Hundreds of Mb/s).The RS 232 signals are represented by voltage levels with respect to ground. There is a wire for each signal, together with the ground signal (reference for voltage levels). This interface is useful for point-to-point communication at slow speeds. For example, port COM1 in a PC can be used for a mouse, port COM2 for a modem, etc. This is an example of point-to-point communication: one port, one device. Due to the way the signals are connected, a common ground is required. This implies limited cable length about 30 to 60 meters maximum. (Main problems are interference and resistance of the cable.) Shortly, RS 232 was designed for communication of local devices, and supports one transmitter and one receiver. RS 422 485 uses a different principle: Each signal uses one twisted pair (TP) line - two wires twisted around themselves.

E. Accelerometer

The 3-Axis Accelerometer consists of three 5 to +5 g accelerometers mounted in one small block. Using the appropriate data collection hardware and software, you can graph any of these components, or calculate the magnitude of the net acceleration. The 3-Axis Accelerometer can be used for a wide variety of experiments and demonstrations, both inside the lab and outside. Here in our paper we have used accelerometers for continuous monitoring as it gives the reading after every 10 sec for X and Y axis. It will helpful for monitoring the parameters like angle observed, steps taken, and distance travelled.

1.2 System Flow

We have one master two slaves in our paper. After initializing LCD it will display project name. Then actually processing starts when serial interrupt came into picture. If it is not detected then it will return to initial stage. And if it is detected then read the request from master then send the data to master via RS485.Select ADC channel 1/2 for digital conversion. Read ADC value which coming from accelerometer after conversion.

Store accelerometer 1/2 value of X and Y axis. Display the value of X and Y axis on LCD.We will get Request from master to access data from slave 1 or slave 2.It will choose between two slaves and access data from that slave.

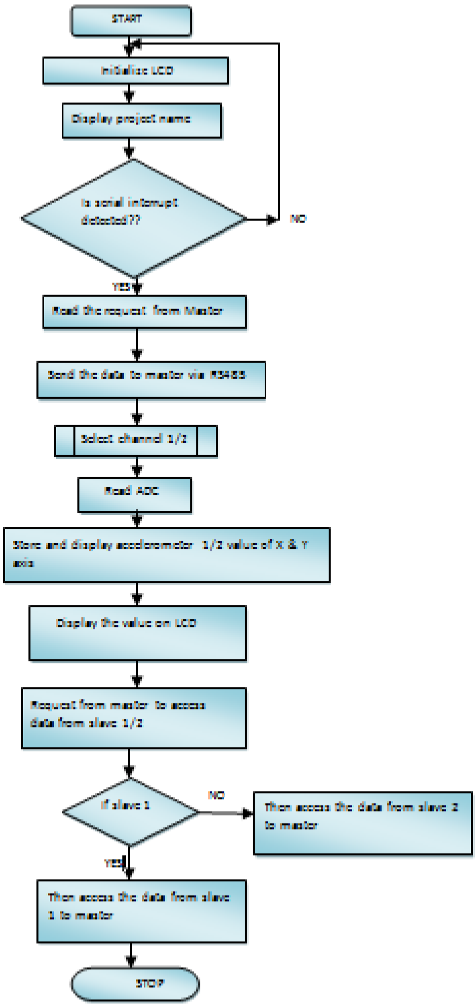


Fig.2 System Flow

We have used below software for system implementation and validation of our results

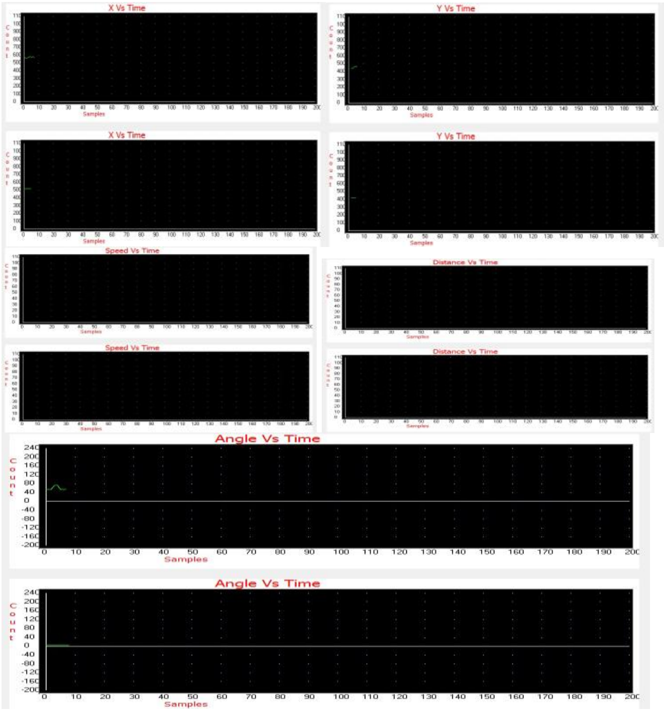
1. Embedded C Programming in Keil.
2. Circuit & Layout Designing: Proteus. 7.7
3. Programming At Pc Using VB. 6.0

2. RESULTS AND DISCUSSION

This work considered four parameters. Four parameters readings generated by accelerometer were Speed covered, Distance travelled, observed angle, steps taken par unit time. For efficient continuous patient monitoring here we are going to consider the four cases of two accelerometers and the three parameters in the initial position and in working position.

Case 1: Initial Position

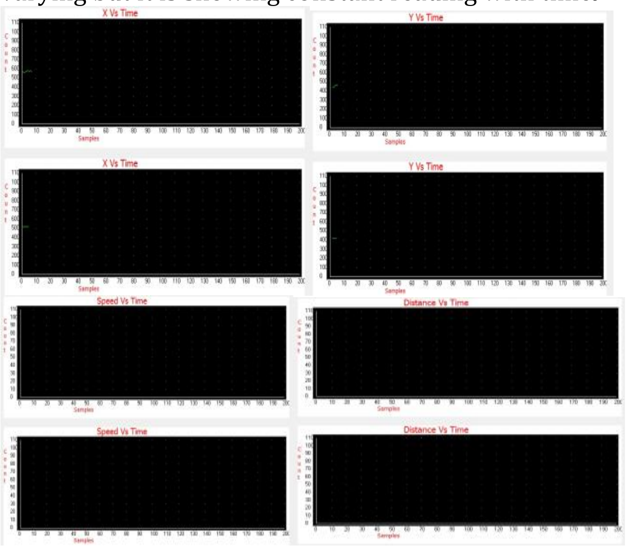
In this case the system is either reset or the initial power supply is applied to the system. In case 1, accelerometer start detecting parameters and it shows the slight variations in graph of Samples of X Vs Time and graph of Samples of Y Vs Time. For initial position, graph of Samples of Speed Vs Time and graph of Samples of Distance Vs time it will not show any changes in both patient's graph. But we can see that there are slight variations in the graph of angle Vs time.

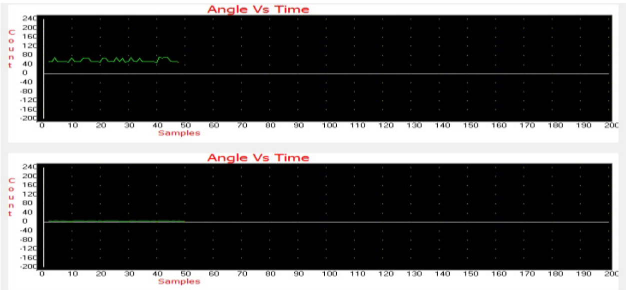


Case 2: Monitoring of patients for 0 to 50 samples

In this case we can see that when patient starts walking accelerometers takes the readings of X axis, speed taken, and distance covered, angle observed. All parameters shows slight variations vs. time. We can see from graph that first patient improvement is better than second patient. It is showing improvement between 0 to 50 samples. Angle of 1st patient is varying more than 2nd one this means that 1st patient can move his/her legs in a normal way. Distance covered of 1st patient is more than 2nd one as we can say that he/she can walk more distance. Speed taken to cover this distance by 1st patient is less but still it is more than the 2nd patient. This is shown in Case 2.In case 2 both accelerometer's X axis showing some variations.1st accelerometer reading is showing variation between 0 to 50 samples w.r.t time.2nd accelerometer showing no variations i.e. it is constant w.r.t time. But both accelerometer's Y axis showing some variations.1st accelerometer reading is showing variation between 0 to 50 samples w.r.t time.2nd accelerometer is also showing slight variations with respect to time. We can see that distance graph of both the accelerometer is varying.1st accelerometer cover more distance than 2nd accelerometer for 0 to 50 samples. In speed graph speed covered by 1st accelerometer started varying slowly but that speed is more than speed covered by 2nd accelerometer between samples 0 to 50. accelerometers.

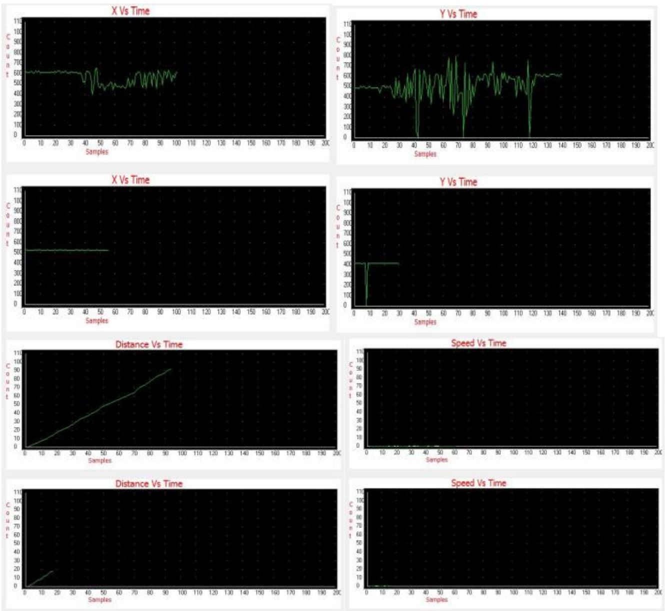
Angle covered by 1st accelerometer is varying slowly with respect to time. Angle covered by 2nd accelerometer is varying but it is showing constant reading with time.

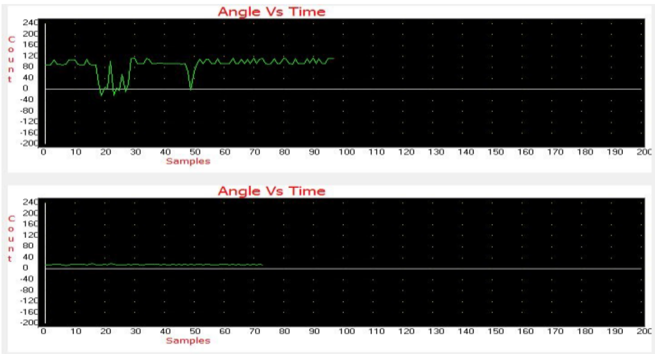




Case 3: Monitoring of patient for 50 to 100 samples

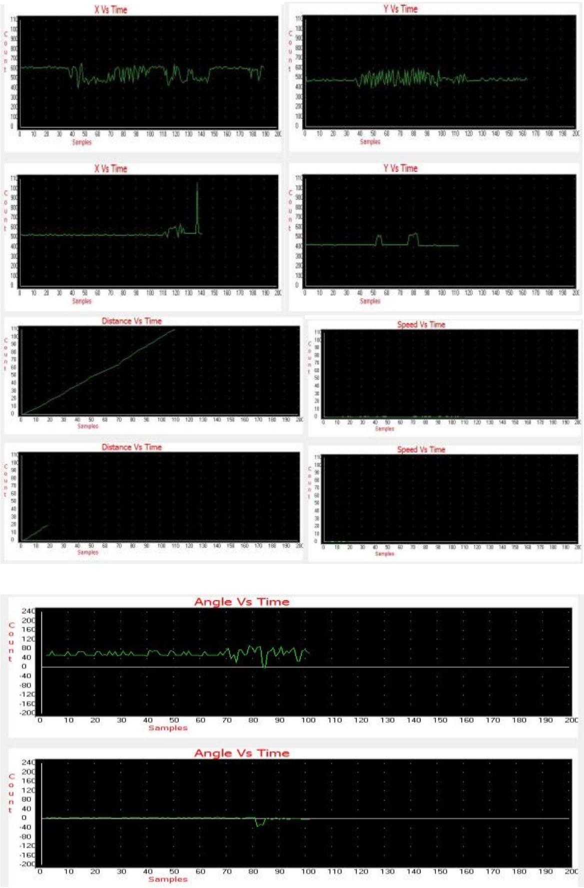
In this case we can see that when patient starts walking accelerometers takes the readings of X axis, Y axis, speed taken, distance covered, angle observed. All parameters shows slight variations vs. time. We can see from graph that first patient improvement is better than second patient. It is showing improvement between 50 to 100 samples. Angle of 1st patient is varying more than 2nd one this means that 1st patient can move his/her legs in a normal way. Distance covered of 1st patient is more than 2nd one as we can say that he/she can walk more distance. Speed taken to cover this distance by 1st patient is less but still it is more than the 2nd patient. This is shown in case 3.Both accelerometer's X axis and Y axis showing variations at great extent between 50 to 100 samples w.r.t time. both accelerometers have started taking readings for samples 50 to 100.Angle covered by 1st accelerometer is now varying more with respect to time. Angle covered by 2nd accelerometer is also varying but then it is showing constant reading with time.





Case 4: Monitoring of patient from 100 to 200 samples

In this case we can see that when patient starts walking accelerometers takes the readings of X axis, Y axis, speed taken, distance covered, angle observed. All parameters shows slight variations vs. time. We can see from graph that first patient improvement is better than second patient. It is showing improvement between 100 to 200 samples. Angle of 1st patient is varying more than 2nd one this means that 1st patient can move his/her legs in a normal way. Distance covered of 1st patient is more than 2nd one as we can say that he/she can walk more distance. Speed taken to cover this distance by 1st patient is less but still it is more than the 2nd patient. This is shown in case 4. In case 4 both accelerometer's X axis and Y axis showing more variations between 100 to 200 samples w.r.t time.1st accelerometer reading is showing variation between 100 to 200 samples w.r.t time constantly.2nd accelerometer is also showing slight variations with respect to time. We can see that in distance graph of both the accelerometer is varying.1st accelerometer cover more distance than 2nd accelerometer for 100 to 200 samples has started varying slowly. But this speed is more than speed covered by 2nd accelerometer between samples 100 to 200.Angle covered by 1st accelerometer is now varying at greater extent with respect to time. Angle covered by 2nd accelerometer is also showing variations but it is less than that of 1st acc.



We can see the hardware setup in fig.3 and the sample measurements two accelerometers for all parameters in table 1.

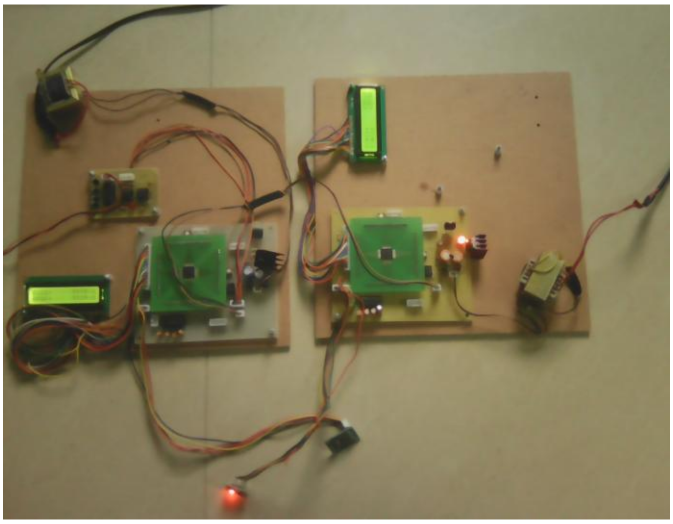


Fig 3. Hardware setup

Table 1: Sample measurements of two accelerometers for all parameters

Date	Time	Weight	Steps	Speed	Calories burnt	Distance	Observed Angle
21-Jul-15	9:42:41	70	7	0.32	2.744	5.6	−105
21-Jul-15	9:42:52	70	9	0.32	3.43	7.2	−61
21-Jul-15	9:43:03	70	11	0.32	4.116	8.8	−120
21-Jul-15	9:43:44	70	13	0.32	4.802	10.4	89
21-Jul-15	9:43:55	70	14	0.16	5.488	11.2	−120
21-Jul-15	9:44:16	70	17	0.48	6.174	13.6	−155
21-Jul-15	9:44:28	70	19	0.32	6.86	15.2	−45
21-Jul-15	9:49:00	70	21	0.32	7.546	16.8	−109
21-Jul-15	9:49:31	70	23	0.32	8.232	18.4	10
21-Jul-15	9:49:42	70	24	0.16	8.918	19.2	−50
21-Jul-15	9:50:36	70	27	0.16	10.976	21.6	−7
21-Jul-15	9:50:49	70	28	0.16	11.662	22.4	−11
21-Jul-15	9:51:00	70	29	0.16	12.348	23.2	−11
21-Jul-15	9:51:31	70	30	0.16	13.034	24	−11

3. CONCLUSIONS

This work presented the gait activity monitoring system for improvement of patient recovery. It uses a tri-axial accelerometer which detects and monitors four parameters like observed angle, distance travelled, speed covered, steps taken through its axis. Total four parameters were considered where 200 samples were taken i.e. 200 samples for each parameter. Results showed that the parameters can be detected and monitored accurately based upon the sensor used. We have shown through graph the 6 graphs per set of samples. We have taken 3 set of samples where we have distributed total 200 samples spam into 3 sets. In 1st set we taken samples from 0 to 50 where there is slight variations of parameters for 2 patients. Similarly we have considered other sets from 50 to 100 samples and 100 onwards. Here we can conclude that 1st patient's parameters are varying more than that of 2nd patient by considering three parameters and accelerometers axis readings. So we can analyze that 1st patient recovery is up to the mark and from his improvement graph medical staff can allow him to discharge and 2nd patient improvement is yet to be done from his graphical report so he has to stay in the hospital till his improvement.

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