Smart System for Personal Assistance in Physiotherapy

Vedant Killa, Yomi Karthik R

Abstract— Proper exercise is the key to a healthy body. Unfortunately, injuries and accidents are on the rise in every corner of the world. Physiotherapy forms the backbone of the recovery process for patients as it enables them to regain their physical strength and in turn, their mental composure. Physical methods such as massage, heat treatment and exercises are used for the treatment processes rather than drugs or surgery. Physiotherapists often guide the patients and ensure that the exercises are performed with the correct intensity and the required frequency based on patient assessment. They consider various prescription factors such as root problems, cardiovascular fitness, general mobility, age, skills and the exercise environment for supervising the exercises. At times, although obliviously, the patients are unable to completely adhere to the required specifications of the body movements. This is a hindrance to their wholesome recovery. The doctors must be continually notified about their progress and must rectify mistakes in their executions. The product described here helps tackle this problem in an efficient manner.

Index Terms— Accelerometer, Embedded System, ATmega328, Physiotherapists, Bluetooth

1. Introduction

Exercises performed in the correct posture and with the desired number of repetition cycles yield better results. In today's times, machines and equipments cater to one end of the spectrum for a certain level of severe cases. On the small scale end, people rely on intuition and basic human counting to perform the exercises. Physiotherapists can guide and instruct the patients only on several occasions. It is not possible for them to be present physically near the patients and monitor their exercise patterns at all times. As human error cannot be avoided, patients often do not perform the exercises quite perfectly, and this remains unnoticed. This problem is well avoided if a wearable device is introduced to them that instructs and monitors their body motion.

The initial calibration and settings are fed in by a supervising doctor. The basic exercise pattern is recorded in a smart way and makes it easier for the doctor. As and when the person performs a set of exercises, a mobile application linked to the sensor unit intimates the doctor about the same. As the device is pre-programmed with specifications needed to perform the exercise, it does not count the sub-standard ones as valid. The various plausible reasons for a faulty movement can involve excessive bending, non-synchronized movement of limbs, speed alteration and even incoherent maintenance of the count. These issues are handled by the smart device worn by the patients. It facilitates communication and sends regular reports to the concerned doctor. In addition, the device allows room for flexibility with customized settings and scheduling of new exercises. The main objective of this device is to provide personal assistance to patients at all times making use of present day modern technology.

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2. Concepts

2.1 *Physiotherapy:* It is a branch of science that heals physical injuries through exercise and improves body movement hence, increasing functionality, strength and balance. Physical therapy is an upcoming area of interest which has many branches including neurology, wound-care, pediatrics, sports, geriatrics, orthopedic, cardiopulmonary and so on. It also enhances quality of life through examination, diagnosis, and physical intervention. It is carried out by professional physical therapists. In many settings, physical therapy services may be provided alongside, or in conjunction with, other medical services. The primary concern in this field is to achieve optimum results by performing the exercises accurately without causing any further damage to the strained body parts. It is described as a long term process where precautions must be taken throughout the treatment period. Regular execution of the exercises in an accurate manner, as prescribed by the physiotherapist in spite of his/her absence will lead to positive outcomes.

2.2 *Bluetooth:* A type of wireless communication used for data transfer between two devices within a small range of distance. The frequency of operation is ultra-high frequency (UHF) in the range of 2.4-2.485 GHz which falls in the unlicensed Industrial, scientific and medical (ISM) Band. It uses the frequency hopping technique at a nominal rate of 1600 hops/sec using a full duplex signal. The physical range of operation goes up to 100m. The key features of Bluetooth communication are low cost, low power consumption and lesser interference. The prerequisite for data exchange is pairing of the devices which authenticate the connection. Information can be exchanged only between paired devices. A unique characteristic of Bluetooth wireless technology is the ability to simultaneously handle data and voice transmissions. It provides users with a variety of innovative solutions such as hands-free headsets for voice calls, printing and synchronization for various gadgets.

International Journal of Scientific & Engineering Research Volume 6, Issue ¼ , È à-2015
ISSN 2229-5518

2.3 *Accelerometer:* It is a device which measures proper acceleration experienced by an object, wherein proper acceleration refers to a free-fall or inertial acceleration by an observer who is momentarily at rest with respect to the object being measured. They are used to sense orientation, coordinate acceleration and vibration, either in single or multiple-axis. An accelerometer behaves as a damped mass on a spring. When the accelerometer experiences acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration. It has a multitude of applications in various fields such as engineering, medicine, transport and navigation.

3. DESIGN

Product Design: This wearable device includes an embedded setup, mounted on an elastic band. The elastic band helps in flexibility of the device, making it easier to be worn by different people in different parts of the body. The electronic components used in this device are as follows:

3.1 *Accelerometer (mma7361):* It is used to measure acceleration ('g force') thus, helps to track movements in the x-y plane. It is the main component used in the device, based on whose values the calibration is done for various scenarios. The accelerometer's stable state involves the condition where the x and y values retrieved from the accelerometer are both zero. Stable state is the initial position when it is idle and before the start of an exercise.

3.2 *ATmega328:* It is a single chip microcontroller created by Atmel. It is a 8-bit AVR RISC-based microcontroller combined 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit converter. The device operates between 1.8-5.5 volts. In this device, both the accelerometer and the Bluetooth module are interfaced to the ATmega328 chip. Hence the data received by the accelerometer is given to the ATmega328 chip, which in turn sends it over Bluetooth to the user's smartphone.

3.3 *Bluetooth Module (HC-05):* It is used to establish wireless communication between the portable device and the user's smartphone. Bluetooth is the preferred mode of wireless communication while exchanging data continuously over a short distance (using short-wavelength within the range of 2.4 to 2.485 GHz). In this device, as the data is being retrieved by the accelerometer, the ATmega328 chip sends the data with the help of the Bluetooth module to its paired smartphone. Data is being sent continuously, as and when the accelerometer gets its values.

3.4 *Li-Ion Rechargeable Button Cells (Power Source):* Rechargeable Li-Ion cells of capacity 3.6V are being used, in order to power up the ATmega328 chip. The portable device consists of an external switch, used for switching on/off the power supply from these cells.

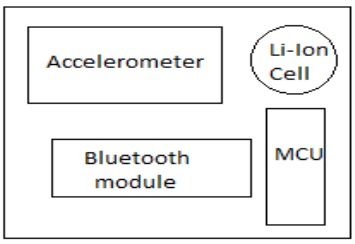

Fig1. PRODUCT DESIGN

4. WORKING

Initially, the calibration is done by the physiotherapist involving an easy two-step process. The information relating to the body movements is fed into the application and the device can be used by the patient. It is stranded to the patient's hand and the power switch is turned on. Hand position is held idle for two seconds, so that the accelerometer achieves a stable state (x=0, y=0). The main objective of the device is to monitor two things:
1) The speed at which the exercise (hand movement) is being done.
2) The direction of the hand movement
Speed is calculated using the following formulae:

$$\text{Up Speed} = \frac{\text{Present height (y)} - \text{Stable state (0)}}{\text{Time taken}}$$

The timer is reset every time the accelerometer reaches the maximum height(Y).

$$\text{Down Speed} = \frac{\text{Maximum height (Y)} - \text{Present height(y)}}{\text{Time taken}}$$

When the patient is moving his hand from the stable state to the required height (maximum height, Y) as per the physiotherapist's advice, the device keeps a constant on the speed at which the exercise is being performed. Likewise, the direction or angle at which the hand movement is carried out is also recorded by taking into consideration data from both the x and y parameters received by the accelerometer. This data is sent continuously to the ATmega328 chip from the accelerometer, which in turn sends it via Bluetooth to a paired smartphone. The smartphone consists of an application which

International Journal of Scientific & Engineering Research Volume 6, Issue ¶ , È à-2015
ISSN 2229-5518

processes the received data. The information received will include the speed as well as the direction at which the arm is moved while performing the exercise. These observations are indicated in two segments of the application. The upper half of the application interface indicates the progress and maintains a count of the performance. Additionally, it also guides the users to adjust their movements according to the required angle. This is pictorially illustrated using arrow marks for the respective directions with an accompanying text message aiding the users' convenience. A variable bar displays the range of the desired speed with a specific color code.

Green indicates that the movement is in accordance with the physiotherapist's advice, while red indicates that the speed needs to be modified. A pause button is also introduced to enable the users to resume exercises after unprecedented interruptions in their routine. The physiotherapist receives a daily update about the patient's exercise pattern and also has a provision of adding an exercise to the patient's daily schedule, hence accomplishing the task of monitoring the patient through remote access.

6 FIGURES

6.1 Flow Diagrams

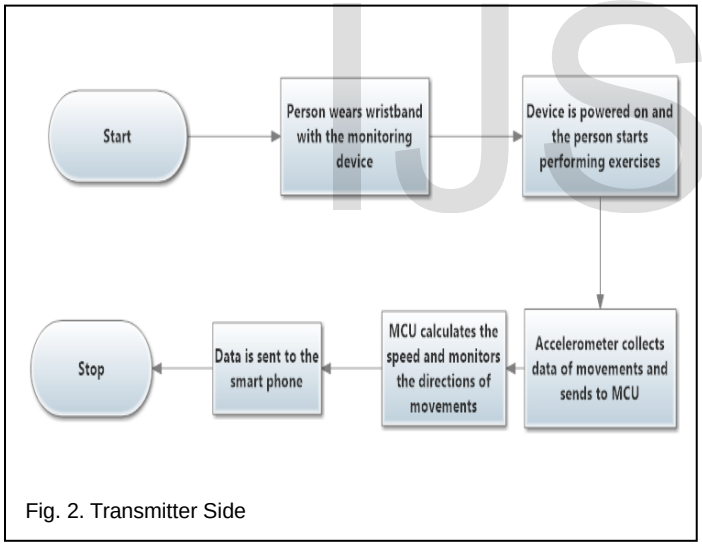

Fig. 2. Transmitter Side

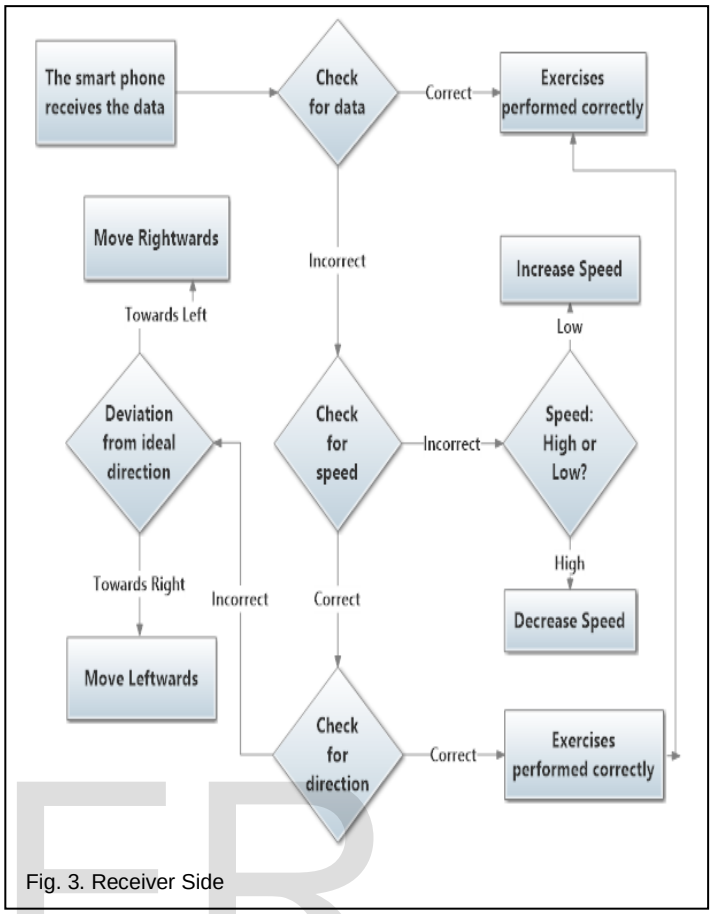

Fig. 3. Receiver Side

6.2 Analysis

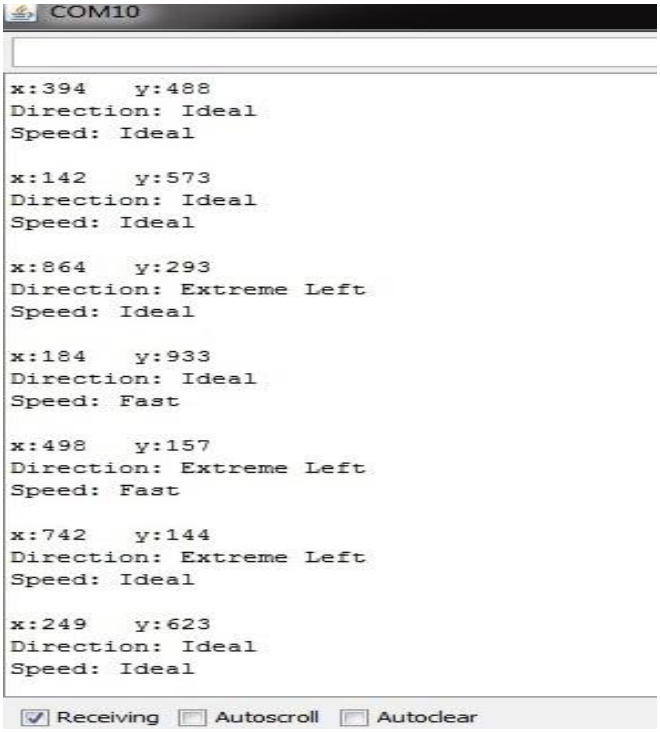

Fig. 4. Analysis at Transmitter Side

International Journal of Scientific & Engineering Research Volume 6, Issue ¼ , È à-2015
ISSN 2229-5518

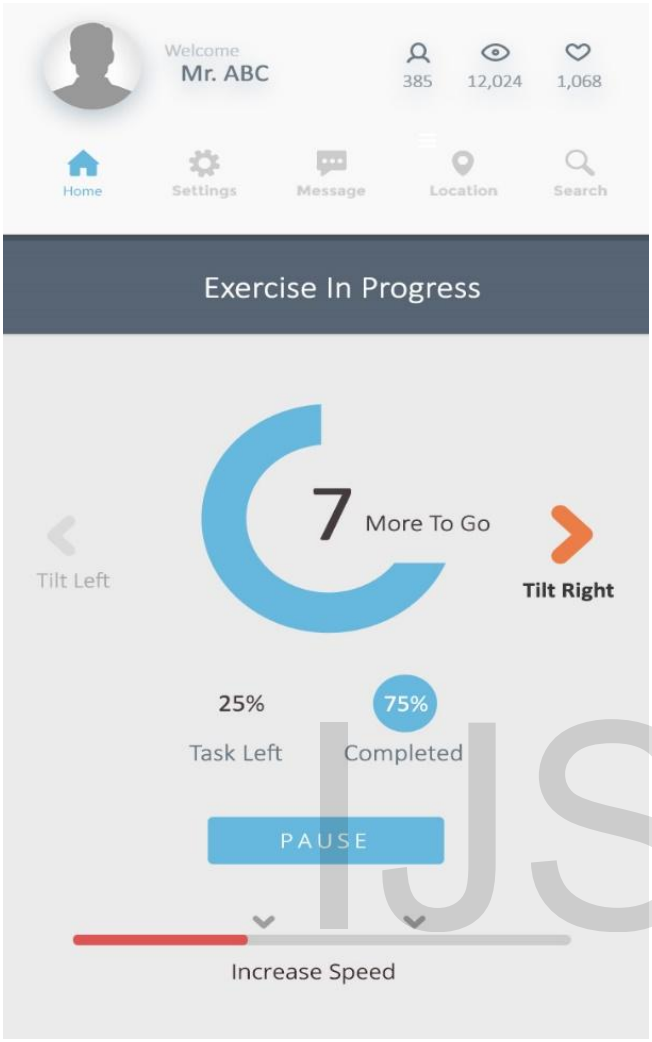

Fig. 5. Analysis at Receiver Side (Smartphone).

7.1 Conclusion and Further Improvements

From the analysis it can be concluded that personal assistance is being provided to a patient with the help of technology. The device effectively monitors the patient's exercise pattern involving the speed and direction of the movements, which is the most important criteria for achieving maximum benefits. Remote access with supervision from the concerned physiotherapist is an added advantage for the user. Since the device is wearable and customizable, it can be used for a wide range of exercises performed for various parts of the body. Moreover, the device is compact and portable which increases it's utility.

The device can be improvised to implement various other functions. This may include correcting the back posture of a person's body, avoiding unnecessary movement of dislocated joints, providing personal assistance to heavy weight lifters and so on.

7.2 References

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