Analysis and Classification of Gait Characteristics

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Abstract- Gait analysis is the most extensively utilised method for detecting and evaluating biological problems and other gait features. Walking is almost unconscious under normal circumstances, when there are no dysfunctional elements impacting the gait. Continuous monitoring, on the other hand, is required for persons who are ambulating. Wearable gait analysis sensors have shown to be a cost-effective, convenient, and effective method of tracking and analyzing the gait cycle. In this context, a wearable sensor unit that objectively evaluates several gait metrics is presented. This research aims to combine gait analysis with inertial sensors like accelerometers and gyroscopes, as well as additional sensors like foot pressure sensors and flex sensors integrated in shoes. The gait shoe proved to be quite useful since it could also measure foot orientation and position. This gadget has a wide range of uses in sports, medical treatments, and biometrics.

Indexed Terms- Wearable Sensors, Gait Analysis, Inertial Sensors, Foot Pressure, Continuous Monitoring.

I. INTRODUCTION

Gait and balance disorders affect 8-19 percent of the elderly, 14 percent of those over 65, and 50 percent of those over 85. [1,2] Falls are the second biggest cause of accidental or unintentional injury fatalities worldwide [3], and poor balance and irregular gait have been associated to an increased risk of falling and hospitalisation. [4]

Individual motions are detected, typical gait patterns are defined, pain-causing concerns are assessed, and therapies to remedy irregularities are applied. All of these can help a person with complicated and difficult-to-understand walking issues make treatment decisions.

Gait analysis equipment and techniques have advanced significantly in recent years. The advancements in how a person's gait is analysed, as well as the technologies used to repair and restore normal gait, make it easier to assess people who have experienced an injury that affects their ability to walk or run more efficiently and correctly. Computer-interfaced video cameras and Force platforms are the most common gait analysis tools. These tools and gadgets, on the other hand, cannot be utilized to assess the gait of people going about their everyday lives or participating in outdoor activities. Various wearable sensors have been created for ambulatory gait evaluations, and while they are light, low-cost, convenient, and non-intrusive to human movement, the gait estimates appear to be erroneous. As a result, the goal of this project is to create a gait analysis system that uses IMUs and foot pressure sensors to evaluate patients' gait throughout their regular activities in order to determine their precise gait.

II. LITERATURE REVIEW

Physical therapists can use gait analysis to build a therapy plan that will assist their patients regain limb function faster, resulting in a shorter recovery period and a faster return to normal (or even enhanced) functioning.

This research introduces a novel Gait Phase Detection Sensor (GPDS) device that works in conjunction with Functional Electrical Simulation (FES) to help those who have trouble walking. The GPDS consists of three

Force Sensitive Resistor (FSR) and a Gyroscope inserted in a shoe that is linked to a microprocessor. The bilateral joint hip, knee, and ankle trajectories were captured and utilised for real-time gait analysis using the Vicon Motion system. [5]

The primary goal of a clinical gait analysis is to help patients understand the cause of their gait abnormalities and make treatment recommendations. The focus of this study is on a clip-on shoe-mounted wearable gait analysis system that analyses gait using an IMU and Digital Infrared (IR) Time of Flight (TOF) proximity sensors. A USB and Bluetooth connection technology are also included in the system to send the parameters for real-time kinetic gait analysis. For IMU data integration, an external Kalman filter is additionally fused with the model. [6]

Gait analysis systems may also give real-time feedback, which may be used to assess how the limbs react to forces applied to them, teach patients how to walk and run appropriately, and advise patients on how to prevent or decrease future injury risks. As a result, the system must give enough and correct information. The designed system in this work employs an accelerometer, gyroscope, ultrasonic sensor, micro switch, flex sensor, and other sensors to determine parameters like foot angle, step distance, step count, cadence, speed progression line, and so on. Foot angle, step distance, step count, cadence, speed progression line, and other characteristics are calculated. The ultrasonic and micro switch sensors are in the quarter of the shoe, while the flex sensor is on the insole. Following the measurement, the gait parameter results are sent to the patient through a GSM module. [7]

Gait analysis for athletic activities has the goal of identifying the athlete's particular capabilities and assisting him or her in achieving maximum performance during a game or activity. The goal of this research is to design a system that will track a sportsman's ability and flexibility. A gait message is delivered to any number entered into the GSM module. Gait analysis for sporting activities aims to determine an athlete's unique skills and help him or her achieve peak performance during a game or activity. The purpose of this study is to create a system that can measure a sportsman's flexibility and ability. Any number placed into the GSM module will get a gait message. They were alternately put underneath the heel to measure heel pressures when wearing lace footwear and other footwear with harnessing straps. The results provided a good idea of capabilities and trade-offs for the two types of sensors.[9]

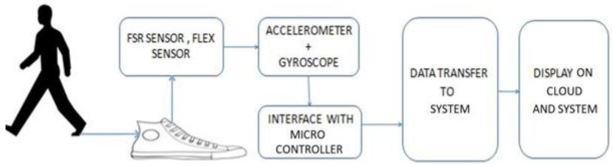
III. METHODOLOGY

The major goal of this research is to acquire gait characteristics in order to evaluate an individual's locomotor pattern and diagnose anomalies and pathologies. This would aid doctors in devising an effective treatment strategy for the patient. IMUs and pressure sensors are used in the proposed approach to calculate step acceleration and cycle time, as well as GRF and foot pressure.

A. Smart shoes with IMU and pressure sensors that can be worn.

The wearable shoes have four force sensors beneath the heel (medially and laterally) and behind the toes (one beneath the first metatarsal head, and another beneath the fourth and fifth metatarsal heads), as well as a flex sensor beneath the plantar fascia, as shown in Fig.1(a). These sensors are used to provide a coarse measurement of the pressure distribution beneath the foot and the foot's pressure distribution. The IMU (MPU6050) is combined with the force sensors and the flex sensor and is positioned immediately above the heel of the foot. A microcontroller with a WiFi module is utilised in each shoe to relay data from the force sensor and inertial sensor to a computer. These data are also uploaded to the cloud at the same time, allowing doctors to view them from anywhere. Figure 1(b) depicts the system's whole process.

(a)



(b)

Fig. 1. (a) The wearable smart shoe (force sensors, flex sensor and IMU). (b) Workflow of the system

- B. Gait Characteristics Extraction Method

1) Normalized peak pressure: The normalised peak pressure is the ratio of the vertical GRF peak value to the subject's body weight. Two peak pressures emerge often in the GRF profile at each position: one after the heel-strike event and the other before the toe-off event. The force sensors get the peak pressure values from the GRF data.
2) Stance ratio: Gait events such as heel-strike and toe-off are determined using GRF data. The cycle time for one leg is equal to the period between two adjacent heel-strike occurrences. The toe-off event divides the cycle duration into stance and swing time. The stance ratio is calculated by dividing the stance and cycle times.
3) Stride length: Using linear acceleration integration, the stride length is computed. The total of the two adjacent step lengths is the stride length.
4) Walking velocity: To calculate the walking velocity, divide the stride length by the cycle duration.
5) Foot Orientation: A gyroscope may be used to calculate the angle of foot orientation in the sagittal and frontal planes and to aid in the detection of minor gait problems by determining the pitch and roll angle.

IV. EXPERIMENTAL RESULTS

A. Experiments

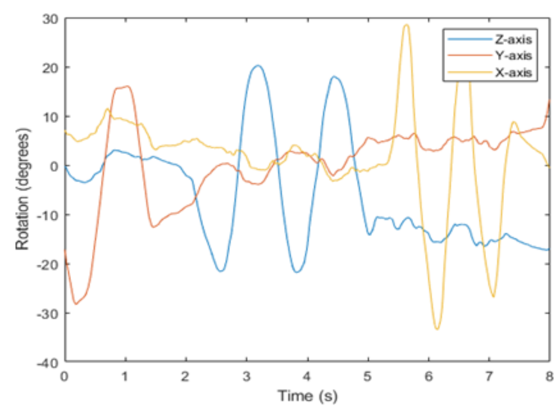
The experiment enlisted the participation of eight male volunteers (Age: 19-21, Weight: 60-86 kg, Height: 173-180 cm). These people were described as having no disabilities or a history of lower-extremity injuries. Each patient went through 15 trials with both normal and atypical walking gaits. The aberrant gait was created by limiting the rotation of the toe joint while walking. To avoid the effects of weariness, a five-minute break was taken before each trial, and the IMU and other sensors on the shoe bottom were verified before each trail to assure uniformity in all studies.

B. Results

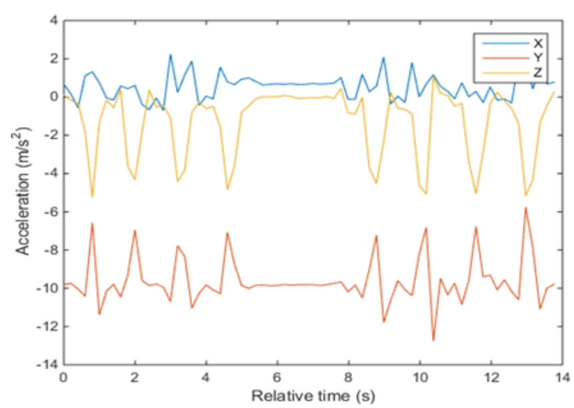
Figure 2 shows the graphs produced from the experimental investigation of our setup. When the graphs created with the established setup were compared to the standard graphs, it was discovered that the produced data and the standard data were almost identical.

CONCLUSION

A pair of wearable shoes featuring an IMU, flex sensor, and pressure sensor was designed in this work to identify normal and abnormal walking. To extract the foot pressure, pressure sensors and a flex sensor were mounted to the shoe soles.



(a)



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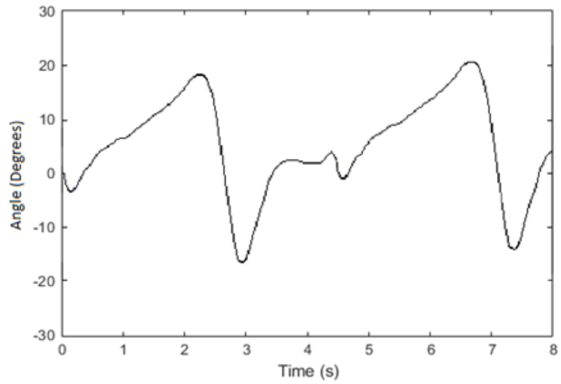

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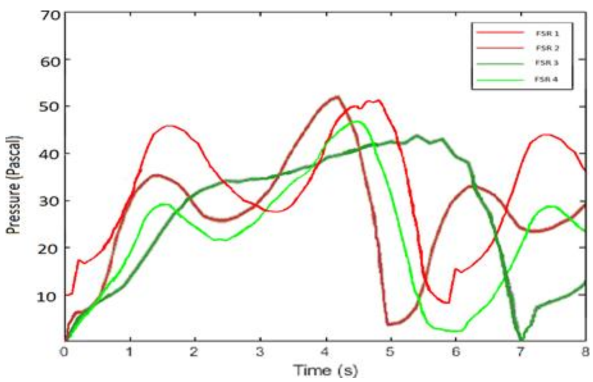

(d)

Fig. 2. (a) Acceleration (b) Foot Orientation (c) Foot Flexion (d) Foot Pressure

To identify the foot orientation, the IMU was attached slightly above the heel in flexion. To process and deliver the data to the user, these sensors were linked to a microcontroller and a Wi-Fi module. The system's performance was validated by a variety of subjects. We also compared the experimental results to conventional gait data and found that the method was quite accurate.

FUTURE WORK

In the future, we want to develop a system that includes an option for assessing gait from the pelvis and knee, in addition to the foot analysis. This would aid in the detection of all types of irregular gaits as well as the tiniest irregularities. The technique may also be used to examine the neurological gait problems that affect the elderly.

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