Concept Generation and Requirements

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SoleTech

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3 Smart Sole Inserts

Team Mission

The team aims to expand and apply the knowledge of the real engineering industry to develop a compact and portable embedded system for gait analysis, provide real-time therapy feedback to doctors, and improve gait balance for patients at the Barrow Institute.

Concept Generation

Pressure-sensitive socks are made of washable and comfortable microfibre laced with Velostat to relay the data required to the microcontroller through copper strips. These will be connected to copper tape to transmit the analog signal generated from the sensed pressure to a wire connected to the microcontroller. The conductive sensing materials will be placed at specific points that the foot normally comes into contact with while walking. The microcontroller will be placed in a separate housing with a daughterboard, linear vibration motor, and accelerometer that will be strapped near the user's ankle. These detachable casings will be sold separately thereby reducing the recurring costs if they break. Haptic feedback will be given using small linear vibration motor devices. The team will make sure that all embedded devices are sealed properly so that the device can be cleaned regularly.

Fig 1. Smart Sensing Sock

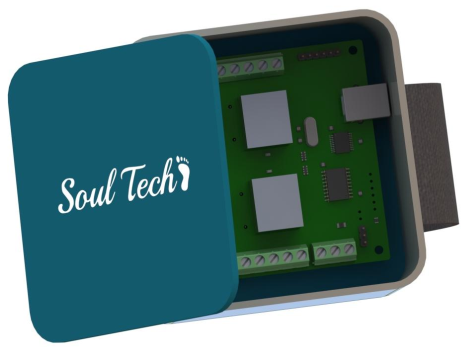

Fig 2. Internal Parts Within the Housing.

The team has used Solidworks to conceptualize designs. In this particular design, the team will incorporate a portion of the smart sensing sole concept. Rather than solely relying on the sole, the team will interlace the conductive sensing material (Veloster) onto the sock's underside. The housing will encase the printed circuit board (PCB) that encompasses the microcontroller, sensors, and actuators.

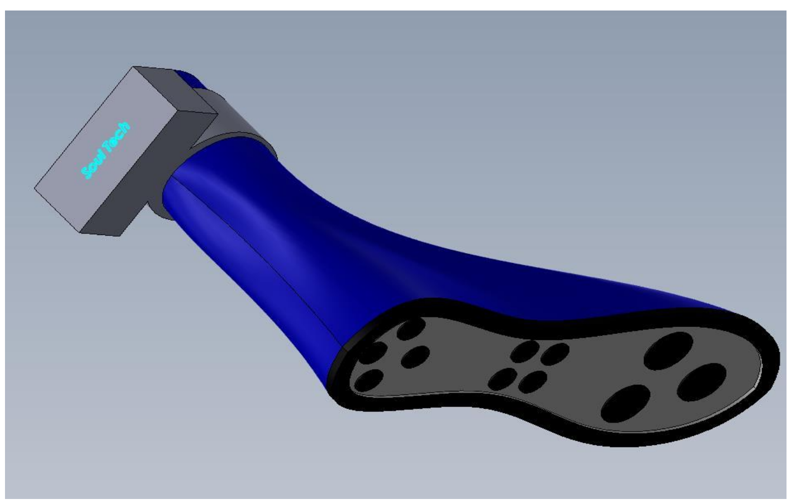

Fig 3. Smart sock for gait analysis

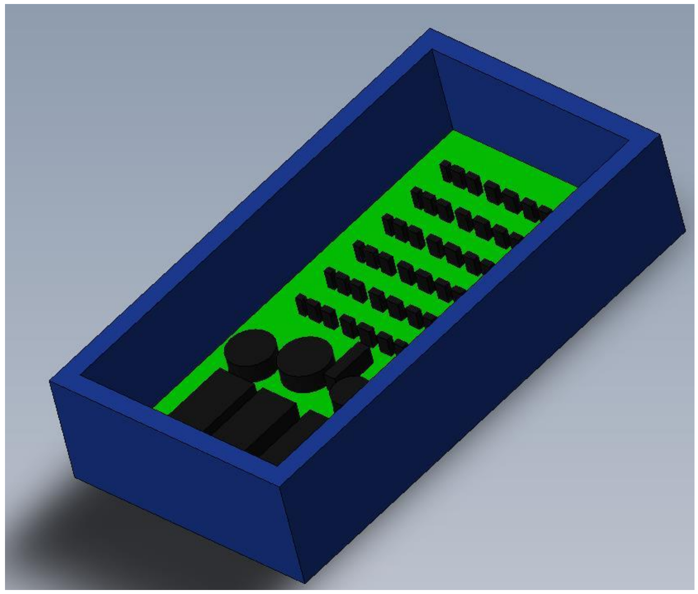

Fig 4. Housing for the microcontroller, vibration motor, and other sensors

In this version of the design, a thin flexible sole with pressure sensors incorporated at key locations is merged onto the underside of the sock. The haptic feedback, microcontroller, IMU, and other sensors will be housed in a casing worn around the ankle.

Fig 5. Controller block

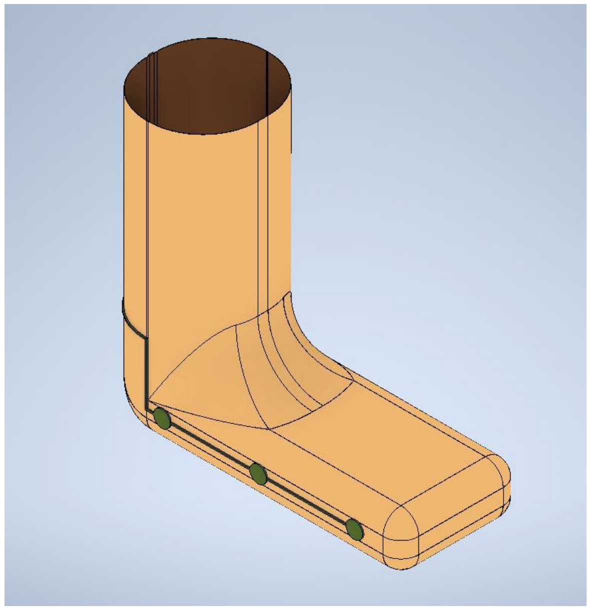

Fig 6. Smart sock Isometric view

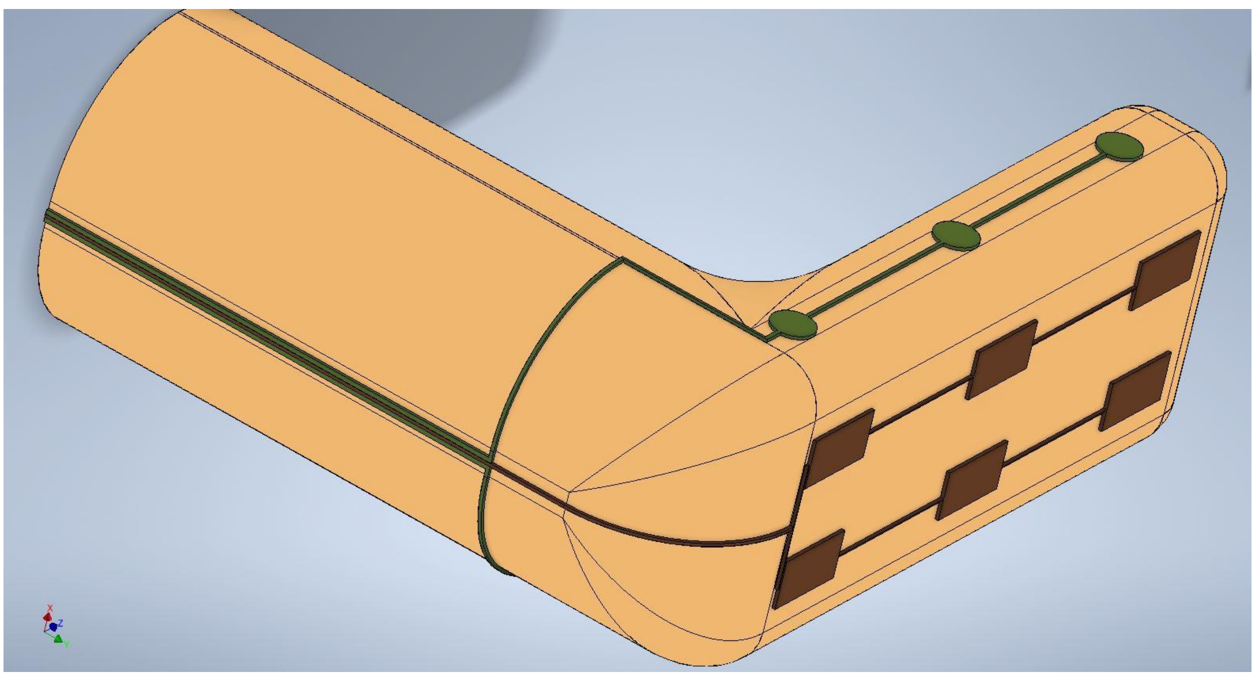

Fig 7. Smart sock bottom right view

The smart socks are docked with 6 pressure sensors and 6 small vibration motors on each sock as shown in figure 7. These are connected to the microprocessor in the controller unit through copper strips. The controller unit consists of a microprocessor attached to a battery and an IMU.

The vibration motors are placed near each pressure sensor to easily indicate the particular wrong position with haptic feedback.

The product will measure the gait characteristics of the user by pressure sensors and indicate which is the correct gait and wrong gait using vibration motors, the spatial measurements of the foot are also calculated using the IMU unit. It is also comfortable and easily cleanable.

Requirements

Functional Requirements

- Pressure sensing: The socks must accurately measure the pressure (weight) applied on the patient's foot with each step to determine weight distribution.
- Bio-feedback: The haptic feedback should be clear and easily distinguishable by the user to provide meaningful feedback on their gait.
- Initial contact detection: The socks should be able to detect which part of the foot made initial contact with the ground during walking.
- Stance time and stance length measurement: The socks must accurately measure the amount of time the foot is in a stance phase and the length of the stance phase.
- Stride measurement: The socks must measure the length of each stride and the number of strides taken during a given period.
- Cadence measurement: The socks must measure the rate at which the user walks to determine their cadence.
- Spatial characteristics measurement: The socks must accurately measure the distance traveled and movement angles by the user during the gait analysis.
- Durability: The socks should be able to withstand repeated use and be made of materials that are easy to clean after each use.
- Data collection and storage: The socks should have the ability to store data or transmit live data for further analysis and sharing with healthcare providers.

Performance Requirements

1. Accuracy: The socks should be able to accurately measure the pressure applied on the patient's foot during gait analysis.
2. Precision: The socks should provide precise measurements of the patient's walking pattern, stance phase time, initial contact, and time shift.
3. Sensitivity: The socks should be sensitive enough to detect where pressure is distributed.
4. Speed: The socks should provide live data to the therapist and patient, with minimal lag time.
5. Reliability: The socks should have consistent performance over time, without noticeable degradation.
6. Durability: Regular wear and use should not damage the socks.

7. Compatibility: Various sizes and styles of footwear should be compatible with the socks.
8. Portability: The socks should be lightweight and portable, allowing for easy transport and use in a variety of settings.
9. Connectivity: Data collection and analysis should be possible through wireless connections between socks and a computer or mobile device.
10. Power efficiency: The socks should have a long battery life and be energy-efficient to reduce the need for frequent charging or replacement of batteries.

Usability Requirements

1. Easy to put on and take off: Socks must be designed to be easy to put on and take off so as not to cause discomfort or harm to the user.

2. Comfortable: Socks should be made of soft, breathable material to ensure maximum comfort during use.

3. Secure fit: Socks must fit securely to prevent them from slipping or moving during use, which can affect the accuracy of the data collected.

4 . Easy to clean: socks must be easy to clean after each use to maintain good hygiene and prevent the spread of infections.

5. User-friendly interface: The device must have a user-friendly interface so that both the user and the therapist can easily interpret the collected data.

6. Light and portable: The device should be light and portable so that it can be easily carried and used in various situations.

7. Durability: Socks must be durable and long-lasting to withstand regular use without breaking or losing precision.

8. Compatibility: The socks must be compatible with multiple devices and software to easily integrate with existing healthcare systems.

Embedded systems devices that the team might need:

1. Microcontroller
2. Linear Vibration Motor
3. IMU (gyroscope and accelerometer)
4. GPS
5. Pressure sensors

The team has to calculate the following from gait analysis:

- Pressure Distribution
- Stance Time
- Point of Contact

- Stance
- Step length
- Cadence
- Spatial characteristics

Processing Sensor Data: Pseudocode

As the patient walks using the Gait Analysis sock, the team can collect the pressure applied, time information, and spatial characteristics of the feet. From the pressure sensors, the team collects data on the pressure distribution, from it the team can collect the initial point of contact and angle of the foot. The team can use a complementary filter that is combined with the pressure distribution and accelerometer data (modified with homogeneous transformation to calculate the angle under the foot while the sensor is attached to the ankle) to calculate the angle of the foot on the ground. The data from IMU can be used to calculate the spatial characteristics and cadence. The team can use 3D simulation tools such as Gazebo or Simulink to map out the all data and footprints to visualize the gait analysis in real-time or for future use.

Contributions

Tatwik: Format of paper, Embedded Systems devices, Processing Sensor Data
Danis: Concept Generation (Figures 1 & 2) and its description
Sriram: Concept Generation (Figures 3, 4, and 5) and its description
Sabareesh: Concept Generation (Figures 6 & 7) and its description
Vishnu: Functional, Performance, and Usability Requirements