Ideation Activity

EGR 555: Mechatronics Device Innovation

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SoleTech

Sai Srinivas Tatwik Meesala, Danis Nugroho, Sriram Rama Prakash,
Vishnu Bhargav, and Sabareesh Karthik

3 Smart Sole Inserts

Ira A. Fulton Schools of Engineering
Arizona State University

Barrow Neurological Institute

Voice of Client/Client Feedback:

Need: Design a portable and light device to perform gait analysis for patients.

Problem: Design a portable and light device (not necessarily a shoe sole) to perform gait analysis for patients. The device must perform gait analysis by measuring the pressure applied on the patient's foot, walking pattern, stance phase time, initial contact, and time shift. The device should also be cleanable after each use.

"So my idea was to have some sort of smart sole device, something that can fit inside of a shoe, that gives the therapist and the patient some sort of feedback. With that, it could give us information on how they're doing when they're walking. Something that can measure the amount of weight that's going through your foot with each step. So we can see if people are leaning more to the right or left side. Also, like the stance time or the amount of time that you're just standing on that foot from when your heel first touches the ground from when you take your foot off like how much time that is. The other thing we might be interested in is information on what part of the foot is hitting the ground first, and in a normal walking pattern, your heel should hit the ground first, and then your foot kind of goes flat" from Kyle Sandoval.

Summarized client needs:

- Measures the amount of weight (pressure) going through the foot with each step
- Gives Bio-feedback (haptic)
- Measures the amount of leaning (lean more to the right/left side)
- Measures stance time/amount of time standing on the foot
- Detect which part of the foot made the initial contact
- Measure stance length and stride
- Measures cadence
- Measures spatial characteristics
- The device must be cleaned after each use.
- Comfortable but the functionality cannot be compromised.

Pugh Matrix (Concept Selection)

From all the ideas that the team brainstormed, the team has selected the 5 best ideas to solve the problem. To select the best solution, the team has created a Pugh Matrix to solve the ambiguity.

Concept selection process:

- Concept selection will first be based on whether the concept can meet the needs of clients
- From the remaining 5 concepts, a Pugh matrix will be used to rank and pick a final concept to move forward.
- The selection criteria are chosen through a voting process and they must be something that can be assessed by simply looking at the concept visually.
- Each team member will score each concept's criteria and the final concept score for each concept's criteria is the total average.

Table 1. Pugh Matrix scaled from 0 to 5 with 5 being the highest score

Selection Criteria	Smart Sock	Smart Sole	Smart Shoe	Computer Vision	Platform
Ease of Hardware Assembly	4.25	4.5	3.5	1.5	4.5
User-friendliness	4.5	4.25	4.25	3	4.25
Environmental friendliness	4.25	4.25	4	4.75	3.75
Effectiveness of Sensors implemented	4.5	4.5	4.25	4.75	4.5
Total Scores	17.5	17.5	16	14	17

Based on the Pugh matrix, the team has decided that the Sock and Sole concept is the best concept based on achievability and resources. The team has decided to work on the two ideas in parallel:

1. Smart Sole
2. Smart Socks

These two ideas are able to satisfy the client's needs. The team feels that the sole comes with a thick base that can protect the sensors, contact pads, and wires. Whereas the socks are more flexible material and fit a wider demographic but the team would have to take care that the

product should be easily cleanable so that it is ready to use for different patients. These both ideas work to generate gait analysis, coming up with two prototypes would allow the team to decide which is more practical and works best for the client.

Sole

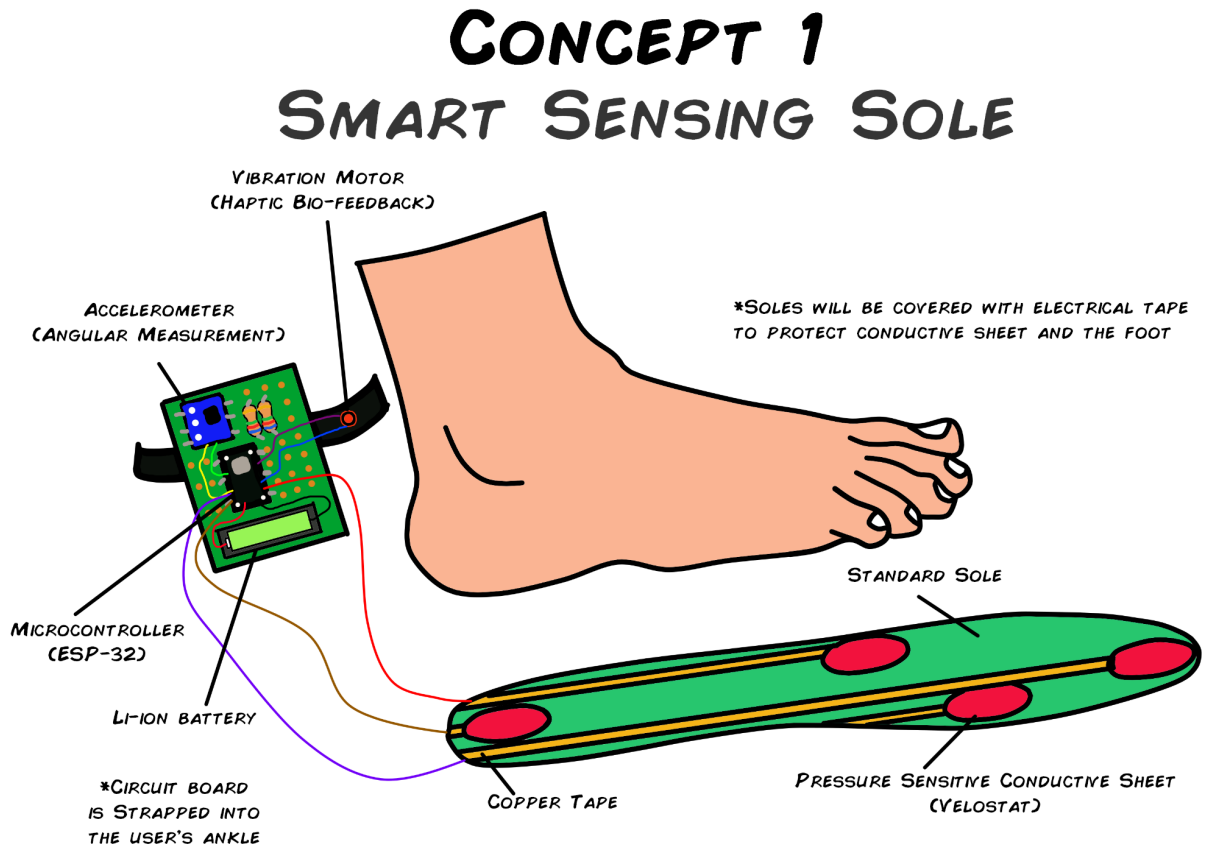

Figure 1. *Smart Sensing Sole*

The sole mainly consists of a conductive sensing material such as a Velostat that will act as a pressure sensor. 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 soles will then be covered with electrical tape to protect the sensors as well as the user's feet. The microcontroller will be placed in a separate housing with a daughterboard, vibrator, and accelerometer that will be strapped near the user's ankle. The vibrator will be used for bio-feedback purposes.

Socks

Pressure-sensitive socks are made of washable and comfortable microfibre laced with Velostat (a thin pressure-sensitive material) to relay the data required to the microcontroller through copper strips. We will try to infuse the controller, and IMU into the socks but if it's not possible, they will be attached to the sock using a detachable casing. These detachable casings will be sold separately thereby reducing the recurring costs if they break. Haptic feedback will be given using small vibration devices.

Figure 2 (a,b,c, & d). Potential models for sock for gait analysis [1]

Embedded systems devices that the team might need:

1. Microcontroller
2. Linear Vibration Motor
3. IMU (gyroscope and accelerometer)
4. GPS
5. Since pressure sensing is essential for gait analysis, the team decided to explore what sensors are available in the market. The team may potentially use
    - Velostat: A sheet of polymeric foil that is electrically conductive and can be used as a pressure sensor by measuring the change in resistance when applied.
    - EeonTex Conductive Nonwoven Fabric: An alternative to Velostat as it is made of microfibre instead of plastic.
    - Graphene-based pressure sensors: A pressure sensor made of graphene because of its high electron transfer rate, large surface area, and increased electrical conductivity.
    - MXenes or nanocomposites-based flexible pressure sensors: MXenes are 2-D compounds consisting of atomically thin layers of metal carbides and carbonitride. They are ideal for flexible pressure sensors, retaining sensing capabilities even when deformed, because of their mechanical flexibility, large surface area, good conductivity, and unique surface chemistry.
    - Piezoelectric sensors: Materials that are sensitive to mechanical stress are used to determine pressure by measuring the voltage generated when subjected to mechanical stress.

Describe ideation best practices your team used.

What worked well?
While brainstorming, the team also created a list of competitors that could be a potential idea. The team analyzed the client's needs and problems to brainstorm ideas and chose the top 5 solutions. Then the team made a pew matrix based on achievability and resources. Then the team concluded with the 2 best ideas that had the best score. The team has also sourced potential sensors to be used for the prototypes.

What didn't work well?
The team thinks they could have come up with more innovative ideas. For now, all team members could not agree on one idea. The team predicts that prototyping two concepts may be a challenge. And the team should also source twice as many resources on a constrained budget.

Contributions

Danis: Voice of client/client feedback, Pugh Matrix, Concept 1: Smart Sensing Sole
Tatwik: Paper format, need and problem, best practices
Sriram: contributed ideas, embedded systems devices
Sabareesh: contributed ideas, embedded systems devices
Vishnu: Summarized client needs, Concept 2: Socks

References

[1] “Sock for gait analysis,” *Dream by Wombo*, 2023. [Online]. Available: https://dream.ai/create. [Accessed: 10-Feb-2023].

Appendix A

Ideas

Some of the brainstormed ideas to solve the current problem:

- Sole
- Socks
- Shoe
- Sticker
- Treadmill
- Platform
- Computer Vision (AR)
- Velostat
- Velcro
- Wireframe
- Cloth
- Combination of platform and socks
- Sensor bands