SoftBreak: Augmented Knee Protection through Fall Detection and Impact Reduction with comfort provided by Alleviation Design

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SRA Track 3 - Sensing the World
SRA Capstone Seminar
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Outline

1. **Introduction:** A brief history and limitations of traditional knee pads.
2. **Methodology:** System Design, Wearability, Sensor Systems, Actuation Systems.
3. **Results:** Final design
4. **Conclusion:** Future improvements

Introduction: A Brief History

- First lateral knee pad was made in 1967 by Dr. Robert F. McDavid which was created to prevent knee injury and reinjury
- Dr. Robert F Mcdavid now has one of the largest sports protection companies of all time
- Created famous HEX parametric design

Fig. 1. Dr. McDavid presenting his knee brace design

Fig. 2a. Example of arm sleeve with HEX design

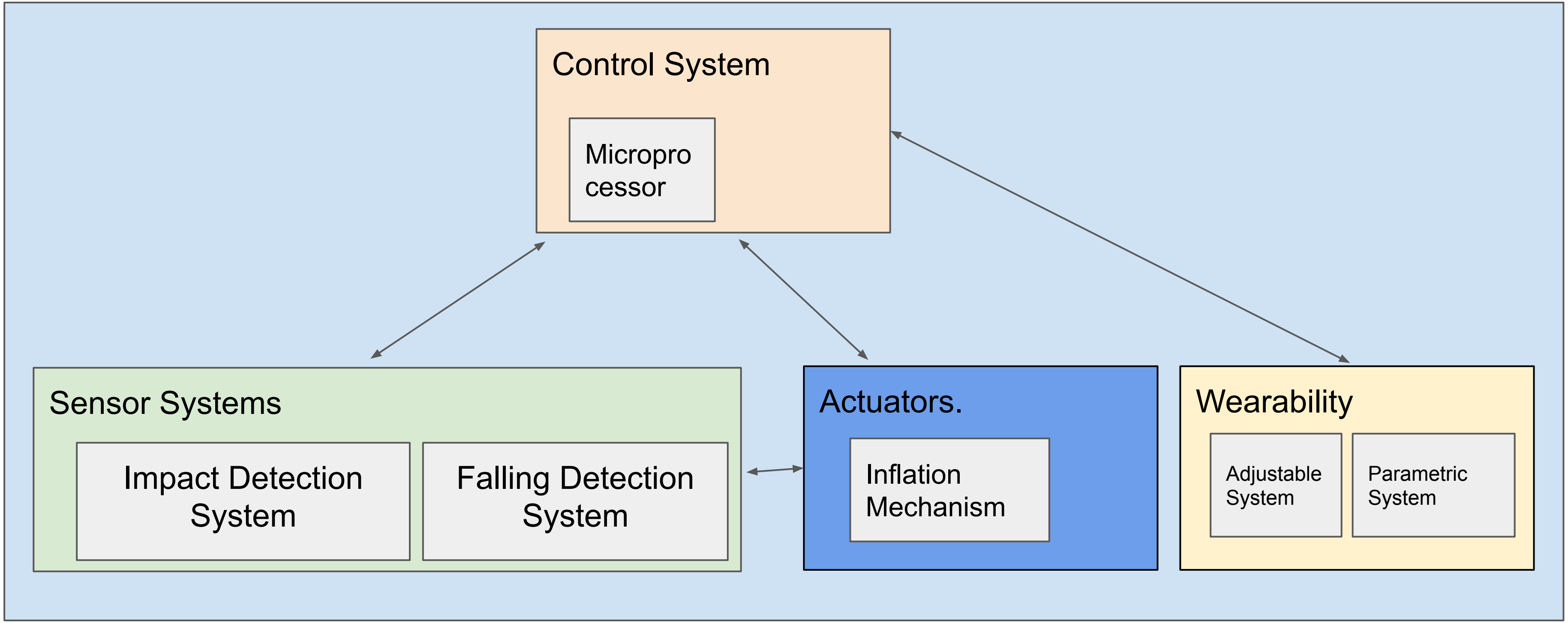
Fig. 2b. Example of knee pad with HEX design

Introduction: Problems

- Current knee pads aren’t comfortable
- Slide off your knee easily & limits athletics ability.
- Not protective as they can be easily rip/tear.

Fig. 3. Example of ripped knee pad after week of use

Methodology: System Design



Wearability: Parametric System

- Purpose: To prevent accidental trigger of the pressure sensors and an outer layer protection.

- Three design variations →

Fig. 4a. Simple Hexagonal Design inflated by an air membrane.

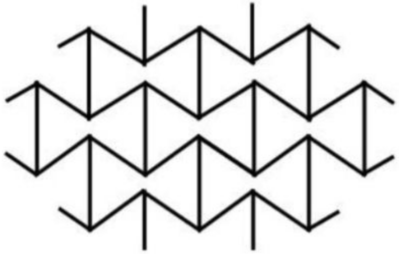


Fig. 4b. The re-entrant hexagonal pattern in 2D.

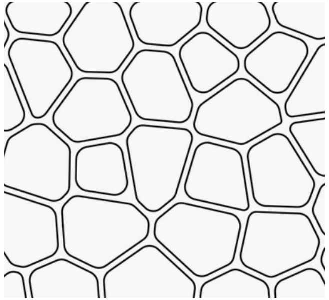


Fig. 4c. The voronoi pattern in 2D.

Parametric System: Entrant - Hexagonal Pattern

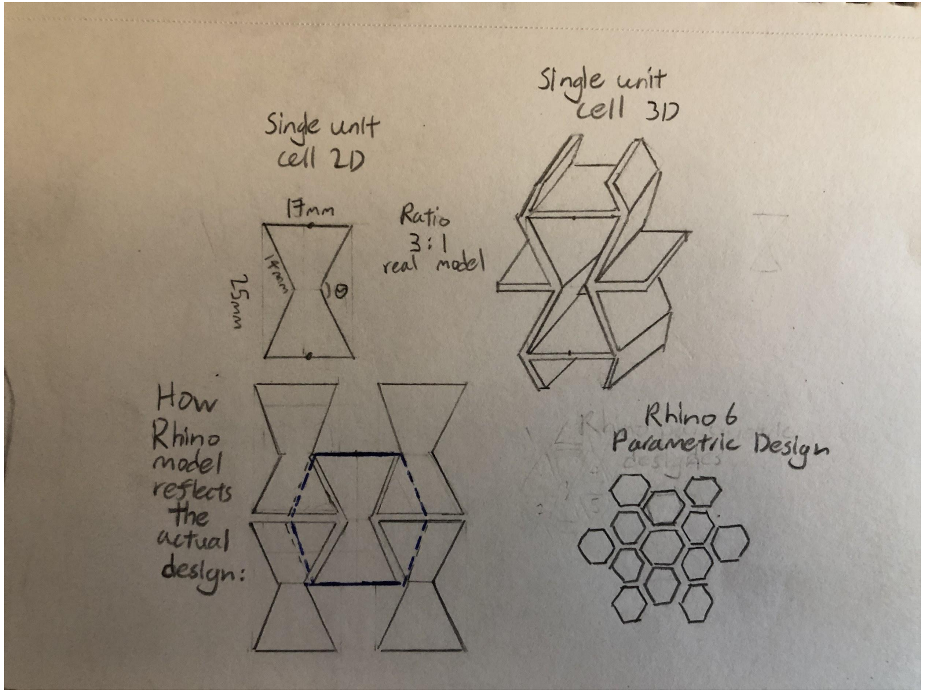


Fig. 5. The parametric design of the outer layer. The first sketch (to the top left) presents a single unit cell in 2D, the second sketch (to the top right) is a single unit cell in 3D. The third sketch (to the bottom right) is the parametric design displayed in Rhino. The fourth sketch (to the top left) is how the Rhino model reflects the actual design.

Wearability: Choosing Straps vs Leggings

$$P = \frac{F}{A}$$

- Which one is more comfortable?
- Manipulating surface area

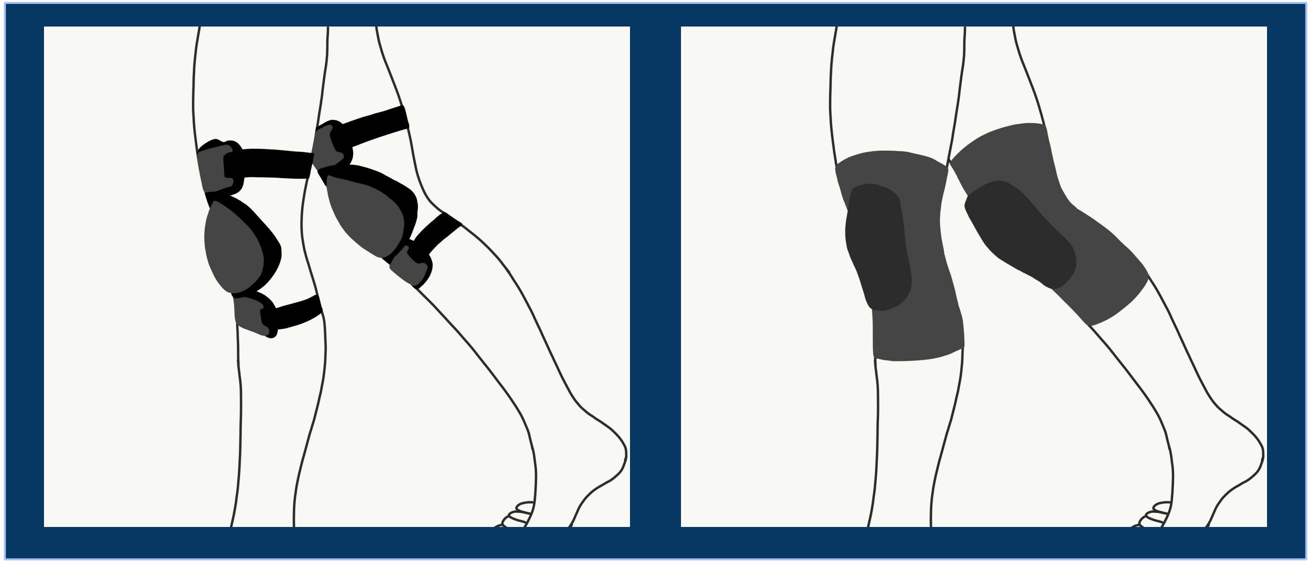


Fig. 6a. Example of knee pads with straps **Fig. 6b.** Example of legging knee pads

Wearability: Adjusting for comfort

- Double-O Kneepad inspiration
- How do we make the knee pad more comfortable?
- Working with fall/impact detection

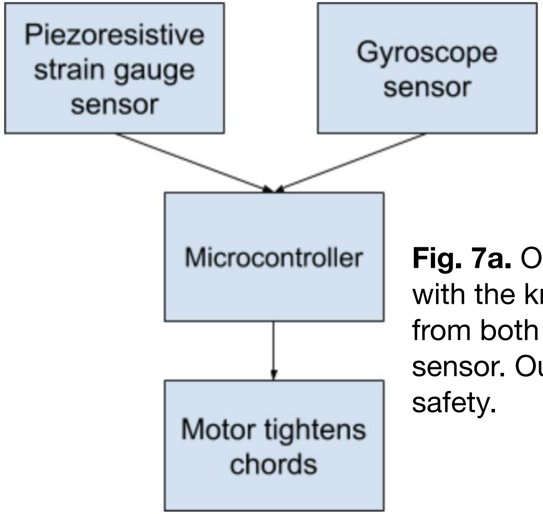


Fig. 7a. Overview of the adjustment control interaction with the knee pad fall/impact detection. Input data comes from both the piezoresistive gauge sensor and gyroscope sensor. Output is tightening the knee pad to increase safety.

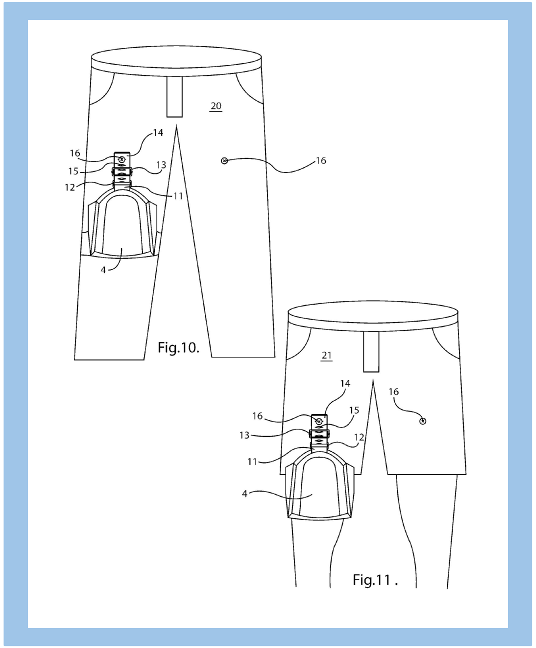


Fig. 7b. 2D model of the Double-O Kneepad. https://patents.google.com/patent/US20070150993A1/en

Adjusting for comfort: Detecting discomfort

- How can we detect discomfort?
  - Photoplethysmogram (PPG) sensor
- Flexible PPG

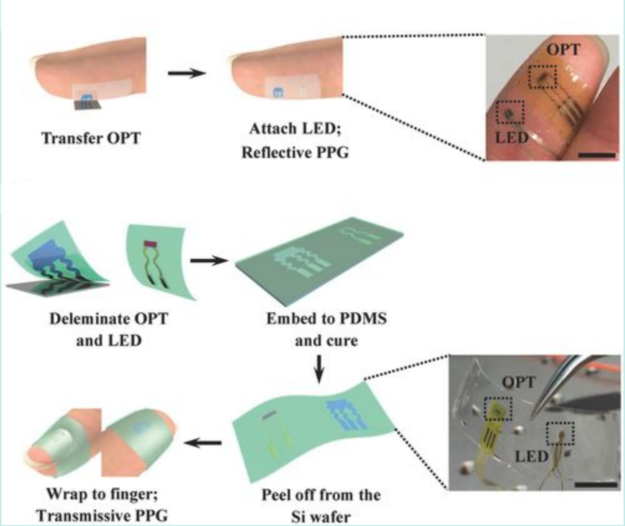


Fig. 8a. Images of flexible PPG sensor.

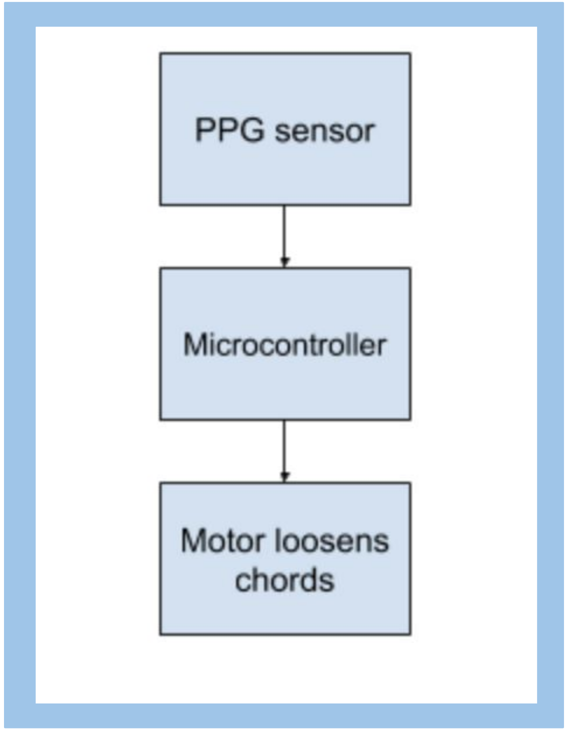


Fig. 8b. Overview of the adjustment aspect of the knee pad control system. Input data comes from the PPG sensor. Output is loosening the knee pad to increase comfort.

Adjusting for comfort:
Tightening/Loosening Mechanism

- Nike HyperAdapt inspiration

Fig. 9. (A) Picture of the Nike HyperAdapt shoe. (B) Can see part of the lacing mechanism on the shoes. (C) Shows the wires and gearbox of the shoe. https://mindtribe.com/2017/02/nike-hyperadapt-teardown/

Adjusting for comfort: Implementing design

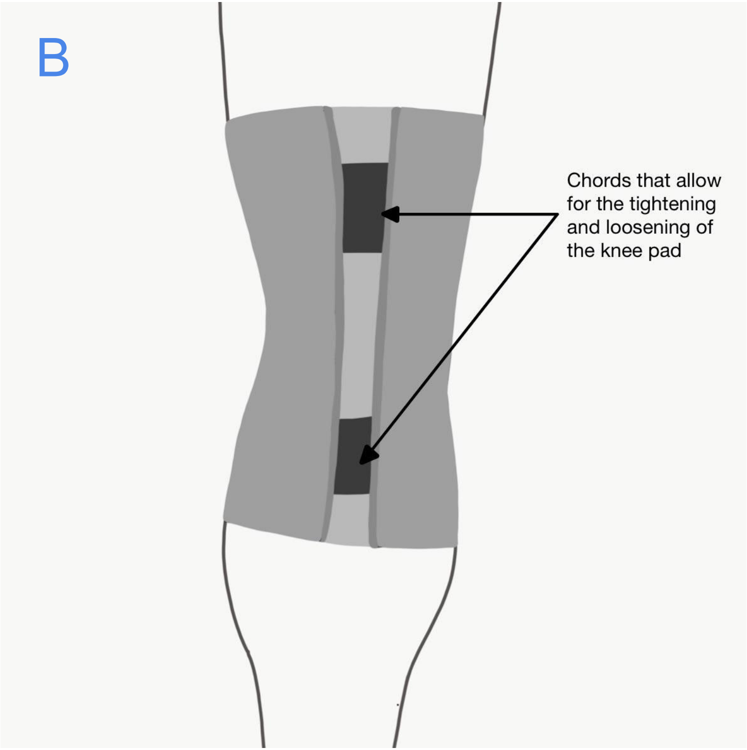
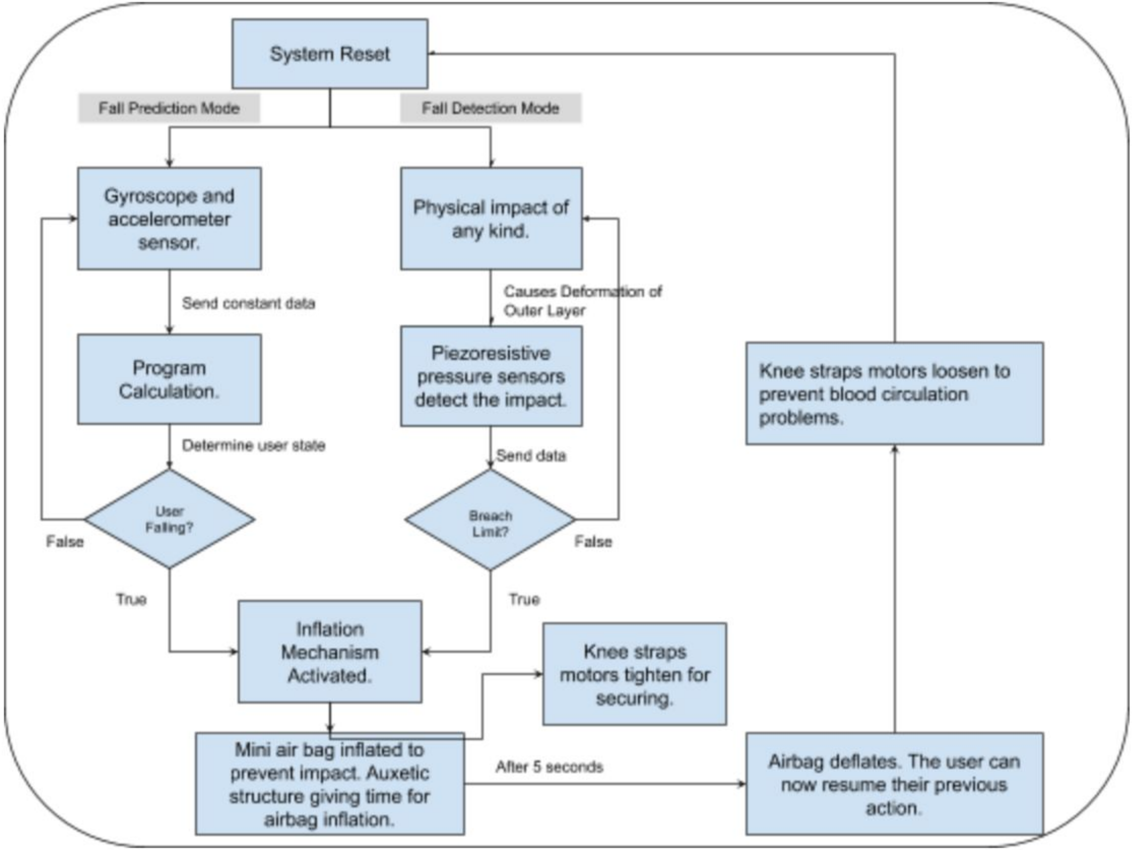


Fig. 10. (A) Birds eye view of a typical shoe with laces.
https://www.kicksonfire.com/the-nike-air-max-lunar-line-has-given-in-to-another-bw-design/
(B) Sketch of the back of the knee pad. Shows part of adjustable mechanism.

Sensor Systems: Control System Overview



Sensor System: Impact Detection

- Piezoresistive Strain Gauge Pressure Sensor.

- Recognizes changes in resistance of the sensor element due to deformation.

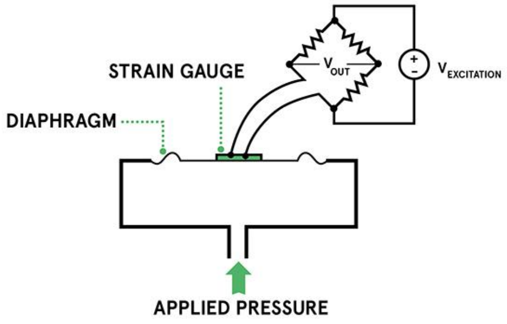


Fig. 11a. Diagram of the piezoresistive strain gauge pressure sensor with its circuitry labeled.

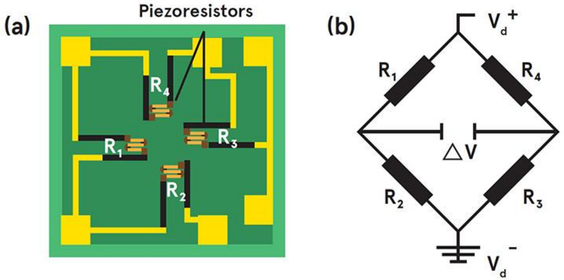


Fig. 11b. Two ways in which piezoresistive elements might be arranged.

Sensor Systems: Falling Prediction Methodology

- if user is in a falling motion it will detect it and inflate the knee pad
- using SensorTile microchip by STMicroelectronics
- testing both accelerometer and gyroscope (finding best difference in the axis) by simulating falling motion
- created thresholds based on testing and will implement in coding software

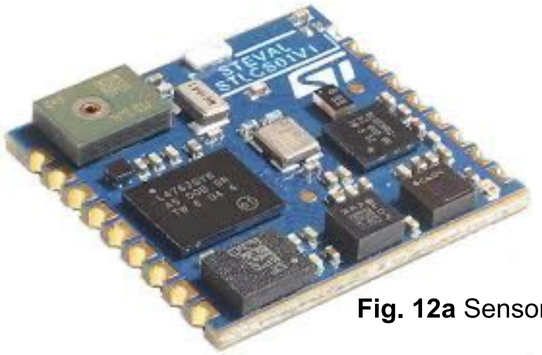


Fig. 12a SensorTile microchip and its sensors

Fig 12b. This is how the sensors will be put on the waist using velcro straps.

Falling Prediction: Analysis

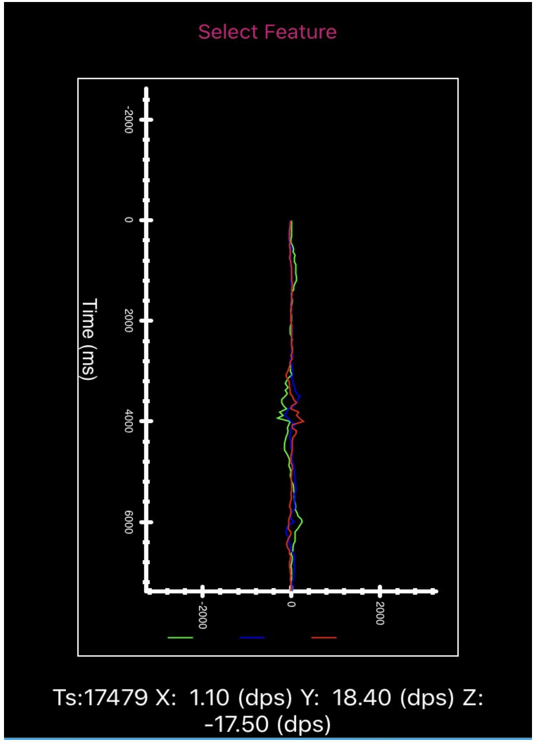


Fig 13a Gyroscope Data of fall

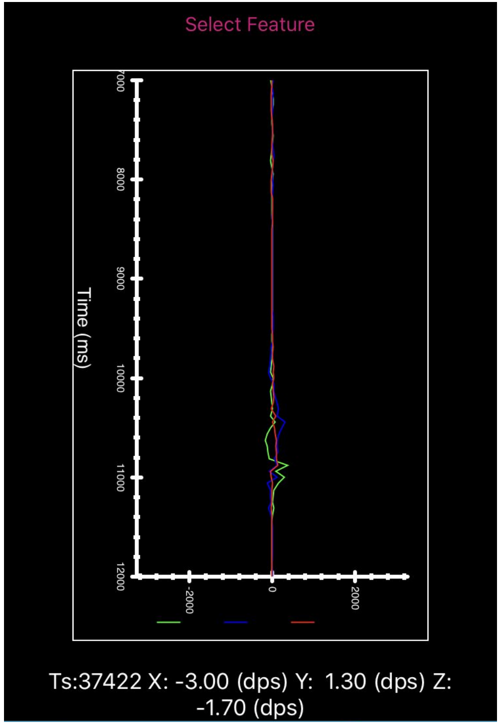


Fig 11b Gyroscope Data of fall

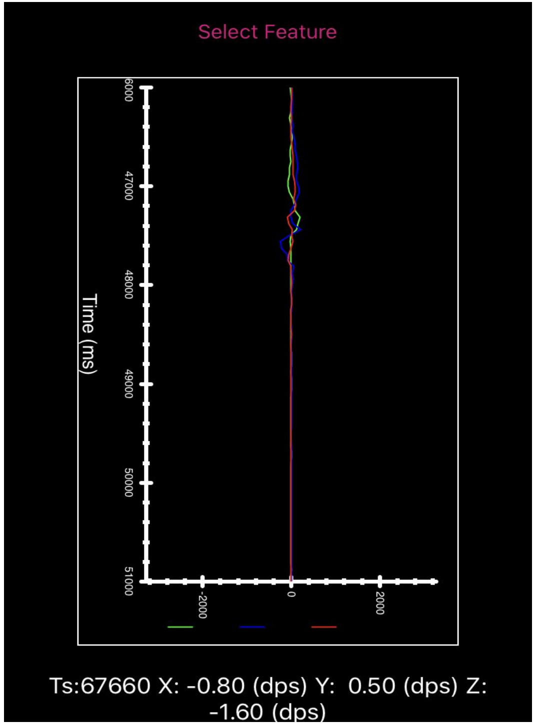


Fig 11c Gyroscope Data of fall

Falling Prediction: Analysis

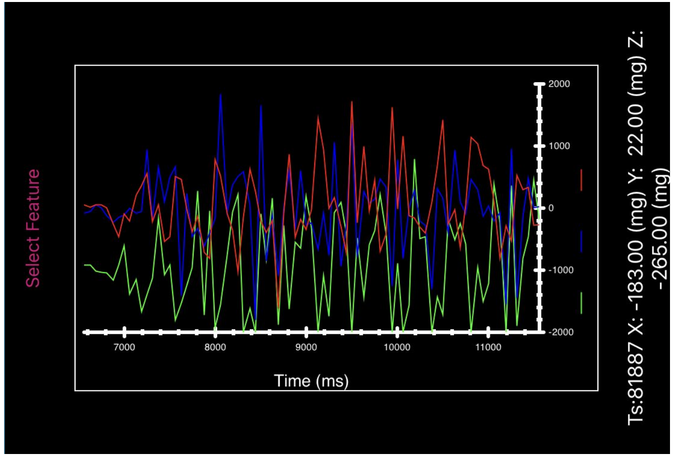


Fig 14a. Accelerometer data while running

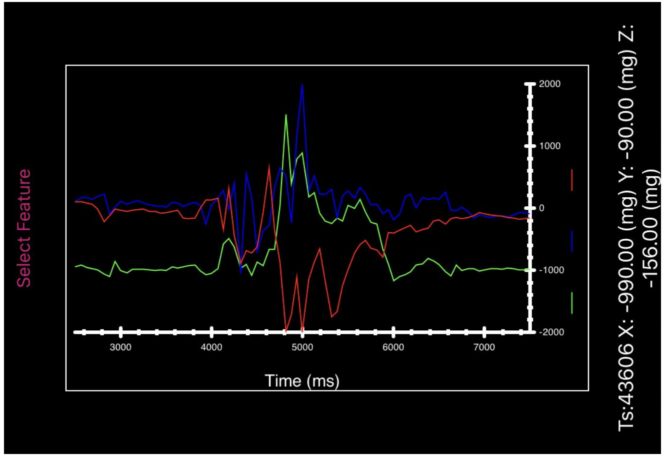


Fig 14b. Accelerometer data while falling

Falling Prediction

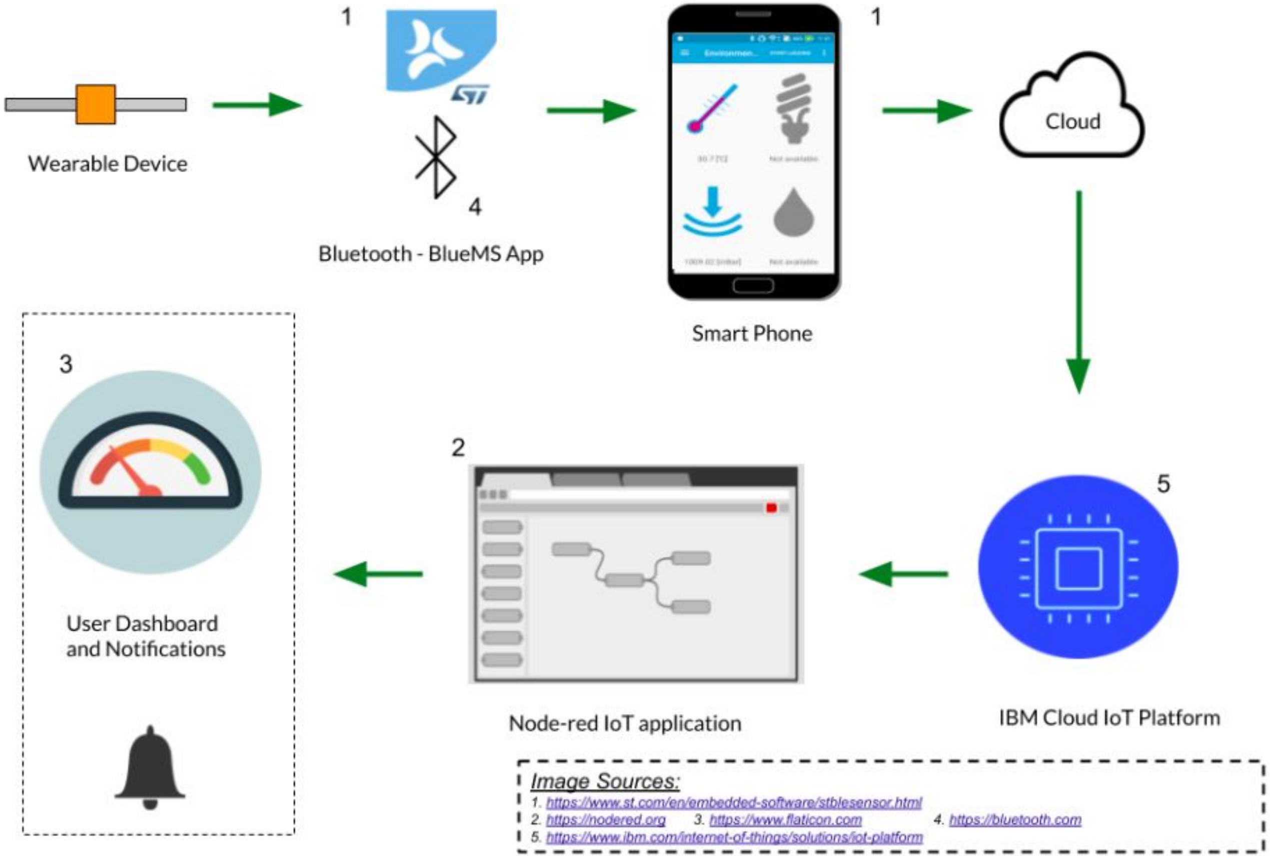


Fig.15 Architecture of data flow

Falling Prediction: Program

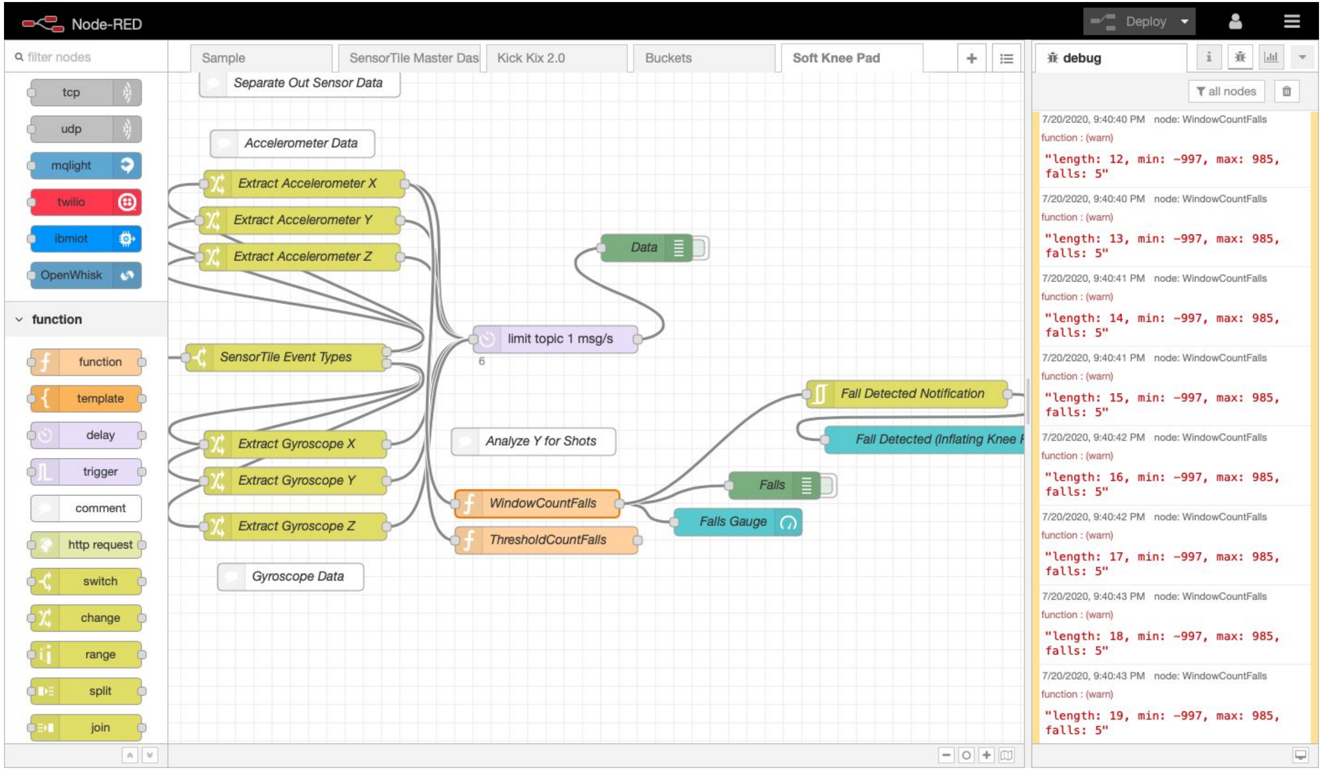


Fig 16. Node-RED flow based program

Falling Prediction: Program

```
// determines the average of all payload values passed in
// over the specified time range
// https://discourse.nodered.org/t/nodes-suggestion-for-timed-rolling-average-and-desynchronised-sum/4933
const range = 20;   // window time millisecs
let buffer = context.get('buffer') || [];
let falls = context.get('falls') || 0;   // the accumulated total so far
//use the gyroscope Y values
let value = Number(msg.payload.AX);
// remove any samples that are too old
var states = global.get( "statecount")||0;
while (buffer.length >= range-1)
{
    // remove oldest sample from array and total
    //node.warn(`removing oldest ${buffer[0].value}`);
    buffer.shift();
}
// add the new sample to the end
buffer.push({value: value});
context.set('buffer', buffer);

if (buffer.length > 10)//looks at a full second of data
{
    var min = 5000;
    var max = -5000;
    for (i = 0; i < buffer.length; i++)
    {
        if (buffer[i].value < min)//for all the data in the half-second, the max and min value are initzialized
        {
            min = buffer[i].value;
        }
        if (buffer[i].value > max)
        {
            max = buffer[i].value;
        }
    }
    if (min < -1000 && max > -500)//if the min and max in within the thresholds, it counts as a shot
    {
        falls++;
        context.set('buffer', []);
        states = 1
```

Fig. 17 Main algorithm/program for fall detection

Falling Prediction

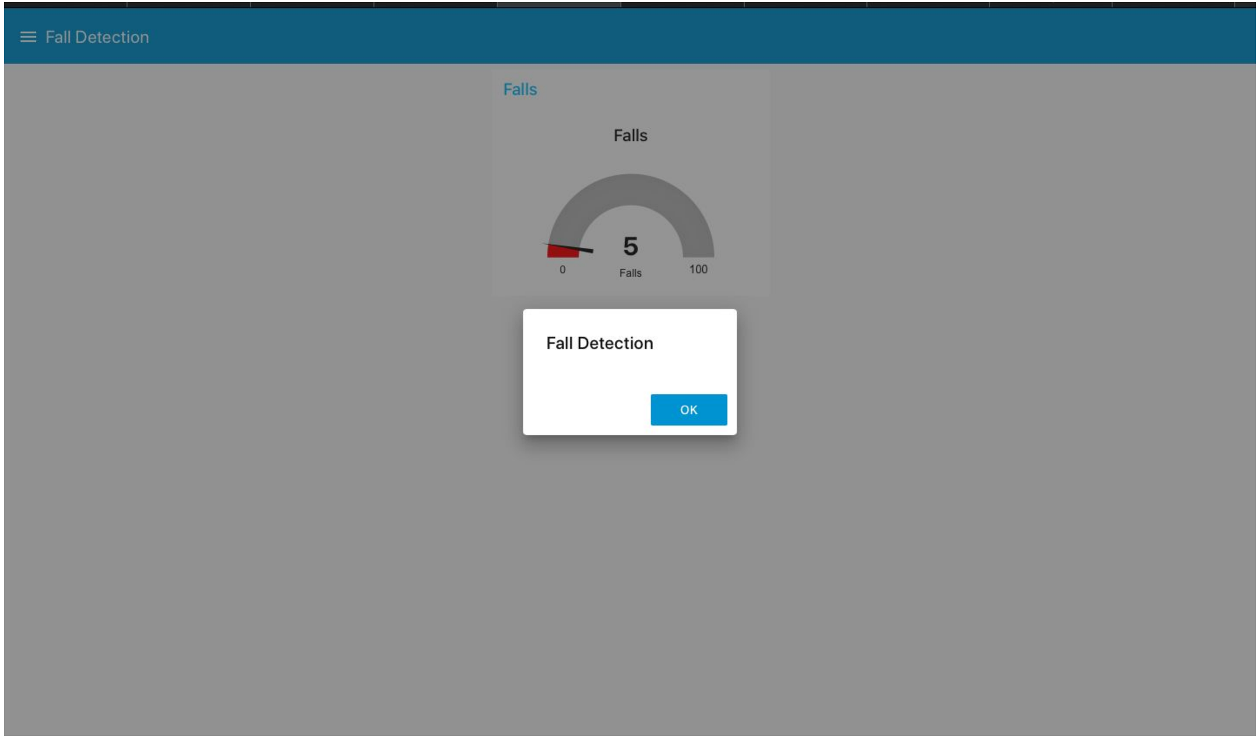


Fig. 18 Dashboard displaying number of falls and notifications for each individual fall

Actuators: Inflation Mechanism

- Inflation utilizing a chemical reaction: Igniting sodium azide for it to decompose into nitrogen gas.
- Main material: Nylon for the mini air bag.
- Previous design: four mini airbags.

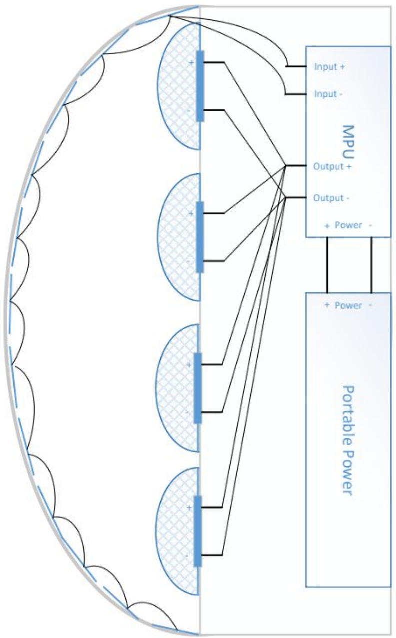


Fig. 19. An old sideways diagram of our device.

Actuators: Inflation Mechanism

- Current design: Inflated airbag designed to cover the knee.

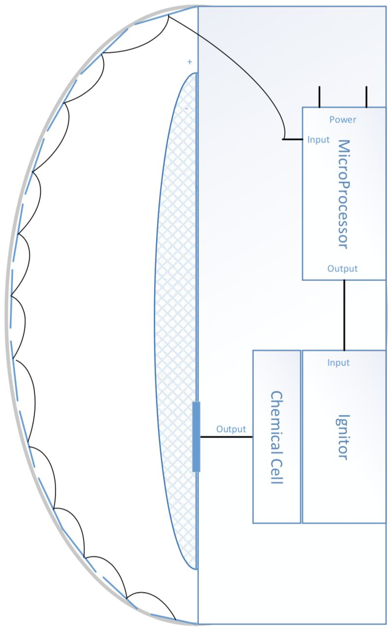


Fig. 20. The current sideways diagram of our device.

Results: Final Model

Back View

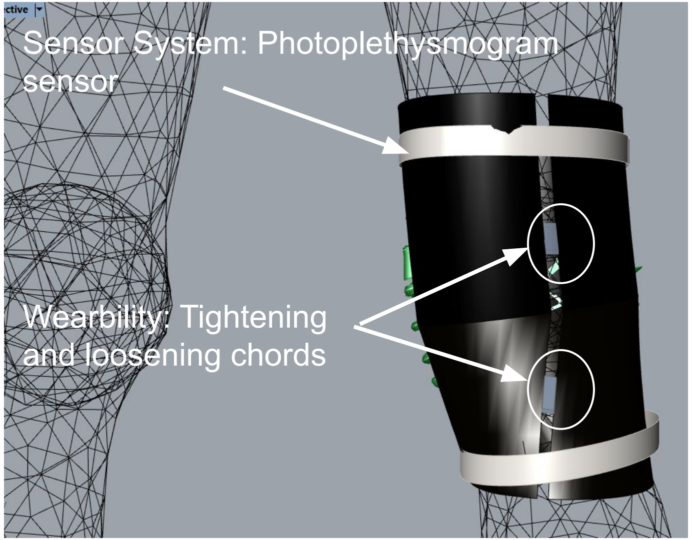


Fig. 21a. SoftBreak Wireframe back view in 3D model.

Front View

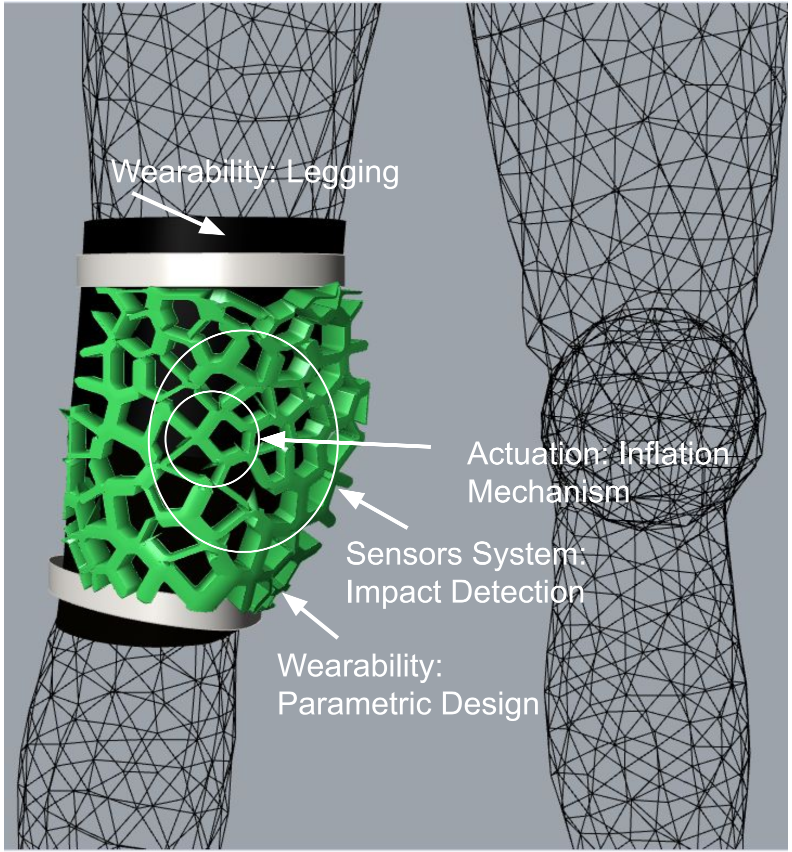


Fig. 21b. SoftBreak Wireframe front view in 3D model.

Results: Final Model Rendered

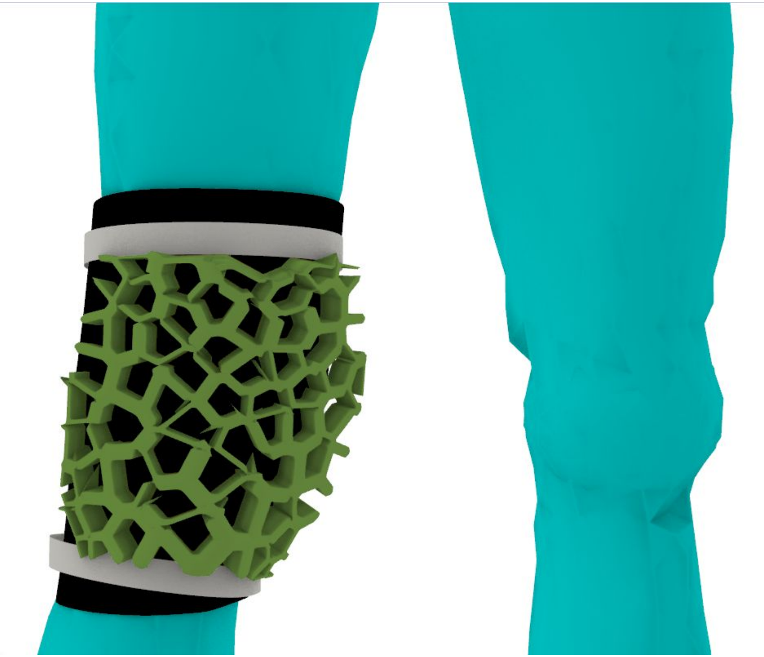


Fig 22a. Rhino 3D design of SoftBreak front view.

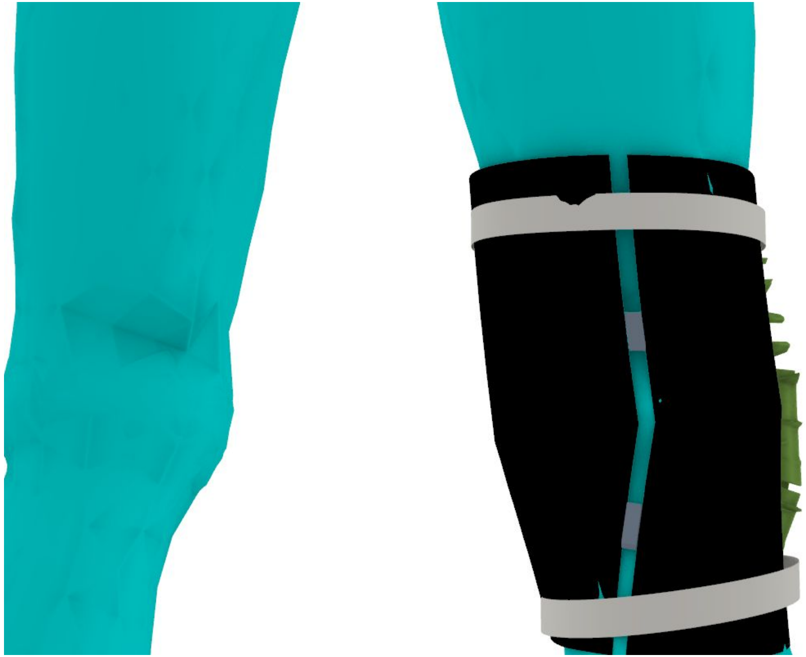


Fig 22b. Rhino 3D design of SoftBreak back view.

Future Improvements

- Better attachments and material for the velcro waist - strap
- Account for change in coefficient of friction because of sweat
- A safer inflation mechanism.
- Ability to handle rough contact surface.

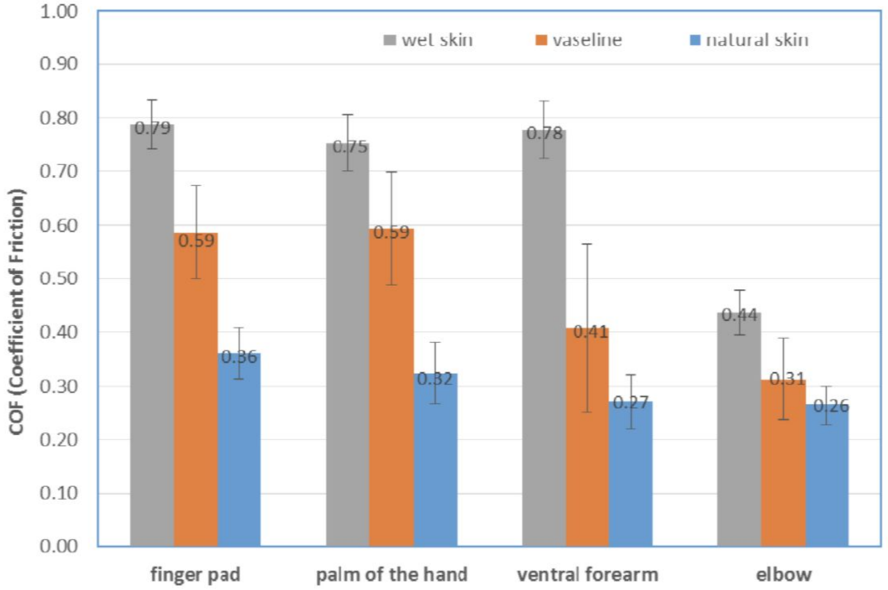


Fig 23. Shows the difference in coefficient of friction based on how lubricant the skin is.
https://www.mdpi.com/2075-4442/4/1/6/pdf

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Thank you for listening!
Any Questions?

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