EquiPack
Team 02

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Advisor: Prof. Salthouse
Overview: The Problem

- Backpacks are frequently misused
  - Most people don’t know how to use the current features
  - Many people overload their bags to a dangerous weight
- How familiar does this look?


What makes EquPack: hardware

- Intelligent backpack with an integrated array of 8 pressure and 1 integrated strain sensor
- Embedded bluetooth and computational hardware used to relay data to user’s BLE equipped Android device
- All embedded components are powered by 4 standard replaceable AA batteries
What makes EquiPack: software

- Software running on Android device estimates backpack’s position and outputs data which can be interpolated to reduce health risks

- “EquiPack” Android application displays output of analytics in a meaningful and graphical manner
  - One (i.e. parent) can intervene when the backpack is abusing the wearer
  - SMS to a subscriber

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Outline of Demonstration

- Demonstration of foam sensor outside the EquiPack to show data collection method

- Demonstration of fully integrated system:
  - User-initiated microcontroller data collection
  - Bluetooth communication
  - Data is presented graphically to user via App
What’s not working:

- Total Weight Sensor (blown power converter, replacement never received)
- Weight pressure sensor normalization
- Gradient plane model integrity handling
- Lower left Strap pressure sensor has shorted out
- Microcontroller is not fitted into enclosure
What’s working: Why 9 sensors?

4 Back pressure sensors.
  - Pressures across flat surfaces can be measured as a gradient plane.
  - In order to characterize a flat plane, we require three orthogonal points.
  - A fourth sensor is added to verify the accuracy of the flat plane model.
  - These points allow us to determine symmetry of the bag and the distance of the contents in the bag.
4 Shoulder Sensors
  ▪ once again the shoulder sensors provide a characterization of the gradient plane along the shoulders.
  ▪ we require three sensors for a complete characterization of the gradient plane and a fourth is added to ensure accuracy of the model.
  ▪ Shoulder sensors again sense symmetry provide for shoulder plane back plane optimization and approximate the initial location of the straps

1 Load sensor
  ▪ The load sensor provides a direct calculation of the total weight of the bag without requiring a complex model
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What’s Working

▪ Weight Sensors Subsystem:
  ▪ Capacitive Foam Sensors
  ▪ Sensing Circuitry

▪ Subsystem on a PCB:
  ▪ μController - LPC824M0
  ▪ Mux/Demux of ADCs
  ▪ Two-Way Bluetooth Communication

▪ Power Systems:
  ▪ 4 AA batteries, converted to 5V with switching regulator
What’s Working

Sensor Characterization
What’s Working, Continued

- **Android Application Subsystem**
  - Graphic display of:
    - Raw sensor data
    - User suggestions (simulated)
  - Persistent user preferences

- **Weight Analytics Subsystem**
  - Simulated Left/Right Symmetry adjustment
  - Simulated Up/Down height adjustment.
  - Slope based algorithm error correction (obsolete)
How do our analytics work?

- Left/Right Symmetry Adjustment
  - Goal: even weight distribution on both sides of body
  - Process:
    - Average values of both shoulder and back sensors on each side.
    - Compare difference to threshold value
    - If below, threshold move to next function
    - If above, send user adjustments and repeat process

- Failure Cases
  - The adjustments briefly become symmetric because of system noise (e.g. rustling of the backpack)
  - Symmetry of individual sensors are severely uncorrelated
How do our analytics work?

- **Center of Mass Calculation**
  - **Goal:** determine if objects are too far back in backpack
  - **Process:**
    - Run center of mass equation
    - Provide information to user for manual adjustments.
  - **Failure Cases:**
    - Back does not create flat interface with back.
    - Backpack has a widely dispersed load, invalidating the point mass assumption.

Center of Mass Equation:

\[
\frac{L^3}{2mg} \left( \frac{p_1}{r_1^2} + \frac{p_2}{r_2^2} \right) + A
\]

- y height correlates to center of mass

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How do our analytics work?

- **Up/Down Optimization**
  - **Goal:** Minimize load on shoulders
  - **Process:**
    - Determine initial position using shoulder pressure gradient vector location.
    - Adjust towards center until back pressure decreases and shoulder pressure increases
  - **Failure Cases:**
    - Significant quantization error in sensors leads to zero valued slopes.
    - Noise in system causes brief changes of increases in shoulder pressure.
    - Backpack is already close to max point at start of algorithm
How do our analytics work?

- Error Handling features
  - Fourth sensor on each plane checks for consistency to model
  - Linear regression formula provides slope measurements to only check for static values.
    (Currently Unused due to heavy quantization error from Microcontroller sampling rate.)
  - 
Overall Specifications

- Low cost ( < $25 mass production)
- Passive or low power ( < 50mW)
- Light-weight (under 12oz additional weight)
- Solution should be applicable to both frameless and framed packs
- Solution provides User with feedback
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Demonstration
Changes made to pressure sensors

- Relay was removed in favor of a transistor
- Diode stack was added to up the circuit Q
- Removed Schmitt Trigger IC in favor of discrete components
Current Schematic

R1 = 49Ω
R2, R3, R5 = 9kΩ
R4, R7 = 120Ω
R6 = 3.9kΩ
R8 = 138kΩ
L1 = 10mH
D = 4148

Q1 = 2N3906
Q2, Q3, Q4 = 2N3904

Advisor: Prof. Salthouse
EquiPack’s user stories

- “As a parent, I want an intelligent backpack for my child so that they can learn to prevent long term injury.”
- “As a parent, I want to be alerted (regardless of distance) when my child’s bag contains an unhealthy amount of weight so that appropriate measures can be taken”
- “As a primary school student, I want an intelligent backpack so that I can be “cool” without risking my health.”
- “As an active person, I want to be able to learn from, control and configure my smart backpack system while wearing the backpack”