Gait Sensing using Fabric-based Inflatable Insole Sensors
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Research Objective
- Gathering gait kinematics data is necessary to operate wearable devices
- Gait Sensors are embedded in shoe insoles
- Generally utilize resistive, capacitive, inductive, fiber bragg grating and soft pneumatic sensing
- Inflatable Fabric based Pneumatic sensors unexplored in gait sensing scenarios

Functional Requirements
- Maximum Payload of each sensor: 900 N
- Average Weight of Person: 77 kgs
- Placement of sensors: Heel and Toe
- Dimensions of each sensor: <= 40mm x 40mm
- Height of insole/Inflation Height: Less than 15mm

Step Response
- Compression testing at Universal Testing Machine
  - 2000 mm/min speed
  - Load cell held at half of the inflation height
  - Settling time of 0.947 seconds

Mechanical Characterization
- Compression testing at Universal Testing Machine
  - 10 mm/min speed
  - Three different regions obtained for Load versus Pressure Profile
  - Load versus Deformation curve shows non-linear characteristics

Working Principle
Sensor Fabrication
- Different designs evaluated for measuring payload of 900 N
- Compression Testing at 10 mm/min
- 35 PSI internal pressure
- Triple balloon sensor design was chosen
- 3 Nylon fabric sockets sewn in series
- TPU balloons put inside each socket
- 4 way plastic connector connecting all the balloons to a single supply

Sensor Design
- One cycle Loading and Unloading test at 210 mm/min
- 55 PSI internal pressure
- 3 Linear Models
  - RMSE (Loading) = 22N
  - RMSE (Unloading) = 22.4N
  - 55 - 57 kg body weight

Hysteresis and Repeatability
- 12 cycle loading and unloading test (35 PSI internal pressure)
- Rate Independent hysteresis lying within 2% error range
- Good repeatability with Peak value Standard Deviation of 1.6N, 1.1N and 1.4N for 30mm/min, 150 mm/min and 270mm/min loading rates respectively for each cycle

Model Building and Validation
- Fabric based soft-pneumatic sensor developed for gait sensing purposes
- Ideal for 55-57 kg person
- Mechanical Characterization tests performed
- Sensor demonstrated Rate Independent Hysteresis
- Good Repeatability for variable loading rates
- Less RMSE value generated in Model validation, demonstrating the sensor’s potential use in gait sensing purposes

Integration & Summary
- Fabric based soft-pneumatic sensor
- Ground Contact Force (GCF) Sensing
- Sensor versus Motion Capture GCF data while walking in treadmill
- Integration and working with a wearable device

Future Works
- Silicone size 9 insole
- Cavities for sensors
- Check Valves

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