PressurePro: Wheelchair Cushion Inflation Control System

Team 17: Sophie Stupalo, Eve Boulanger, Inaara Ahmed-Fazal, Meghan LaCoste, and Hannah Cardoza

Background & Motivation

Pressure Ulcers Among Wheelchair Users:

Pressure ulcers that develop underneath the sit bones (ischial region) are the most common health complication among wheelchair users [1]. They are especially common among those with complete spinal cord injuries due to their lack of sensation and mobility.

of individuals with SCI experience a pressure ulcer once in their lifetime [2]

Recovery can take up to **several months** at home, in a long-term care facility, or in hospital [3]

The cost of healing a pressure ulcer can range from **$500** to **$70000** [4]

Stakeholders: *Individuals with complete spinal cord injuries, other wheelchair users, caregivers, occupational therapists*

Limitations of Current Solutions :

The ROHO® Quadro Select® is one of the most commonly prescribed wheelchair cushions for individuals who are at a higher risk of developing an ulcer [5]. It sets itself apart by its ability to distribute pressure independently amongst its four quadrants.

However, it is only effective at certain inflation level specific to each patient, as determined by an occupational therapist. This level of inflation is difficult to maintain due to the prevalence of leaks [5]. Both over and underinflation of the cushion increases the risk of pressure ulcers [6].

Currently, users are required to manually and subjectively check and correct inflation levels, requiring physical effort, mobility and daily adherence [6]. This also leaves them vulnerable to leaks that occur in less than one day, as unsafe inflation levels can lead to pressure ulcers within hours [6].

The most common cause of adverse events and pressure ulcers for the ROHO® Quadro Select® is the failure to maintain safe inflation levels [7].

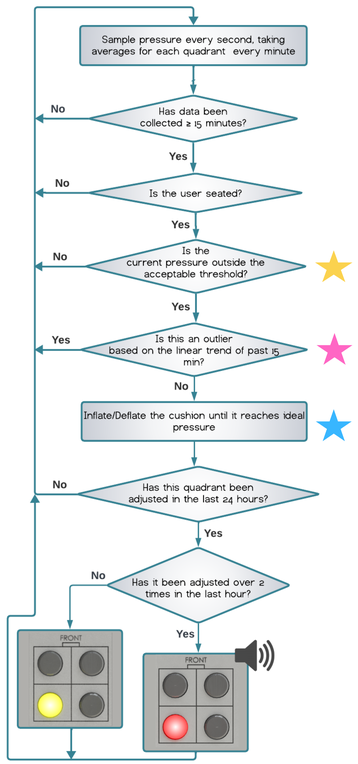
Project Objectives

Design attachment for ROHO® Quadro Select® Cushion that reduces risk of pressure ulcers by:

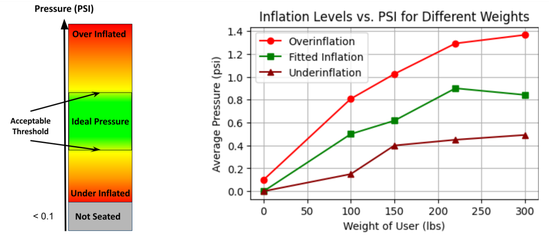
1. Continuously monitoring and correcting internal pressure levels to OT recommendation
2. Alerting users of quadrants with leaks for repair

Designed Solution

Logic Flowchart



Mapping Pressure to Inflation

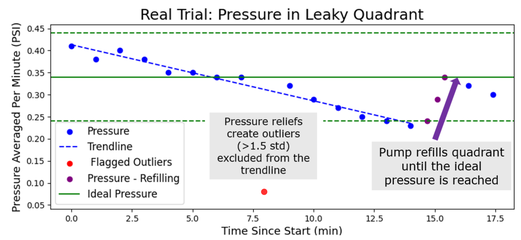


Determining Outliers

The algorithm had to differentiate real leaks from pressure reliefs and system noise when determining when to adjust inflation.

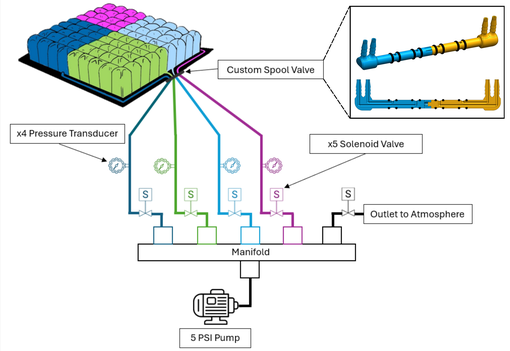
We determined that a linear trend of the past 15 minutes had the best specificity and quickest response time on sets of simulated data ranging in noise and leak rates. Pressure readings that do not align with the trend of the past 15 minutes are classified as outliers.

Correcting Dangerous Pressure levels



The system approximates the pump time required to fix the difference in pressure. After each interval it pauses to sense the error, repeating until the error is less than 0.01 PSI.

Mechanical/Pneumatic System

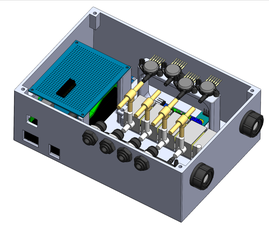


The solution is a low-pressure (<3 psi) pneumatic system which detects the pressure in each quadrant of the cushion and can inflate or deflate as needed.

Starting from the cushion, a custom spool valve is used to access each quadrant separately. The pressure in each quadrant is then measured using pressure transducers. Based on these readings, an algorithm controls the opening and closing of solenoid valves which control the channels to specific quadrants. The algorithm also switches the air pump on and off.

If deflation is required, the outlet valve and the valve connected to the specified quadrant are opened to expel excess air to the atmosphere.

Device Housing



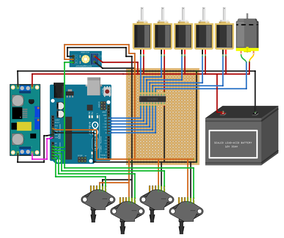
The mechanical/electrical system is housed compactly underneath the seat of the wheelchair through straps. One can quickly and easily separate these parts from the cushion if needed for leak repair.

This system communicates to the user interface, which can be attached to the arm-rest, for easy access to controls and visual indications.

Electrical System

The electrical system connects the sensors, solenoid valves, and pump to a Darlington transistor, Arduino, and a battery to be able to power and control the components.

The pump and solenoid valves are controlled using a Darlington transistor. The pressure transducers are connected to an Arduino Uno which receives pressure data from the cushion. The whole system is powered by a 12V battery which is stepped down to 9V via a voltage regulator to power the Arduino. The 5V source from the Arduino Uno is used to power the smaller components.

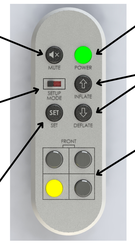


User Interface

Allows user to mute alerts regarding leaks in the cushion

Unlocks all quadrants during cushion setup. Red means Setup Mode is off and green means Setup Mode is on.

Allows ideal pressure levels to be set for each quadrant when in Setup Mode

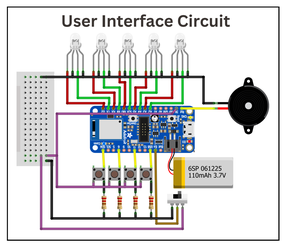


Visually indicates system power and charge level

Allows inflation/deflation of cushion when in Setup Mode. If both buttons are pressed simultaneously when not in Setup Mode, the pressure in each quadrant resets to its last set ideal pressure.

Visually indicates if a quadrant has a leak

- Yellow light if system detects small leak over past 24 hours that can be compensated for but should be repaired by the user
- Red light if system detects significant leak that cannot be compensated for and must be repaired immediately



References & Affiliations

Acknowledgements:
We thank Professor Jenny Howcroft for her invaluable support as our advisor and for facilitating our engagement with stakeholders via the Stakeholder Café. Our gratitude also extends to Permobil for their generous cushion donation as well as funding we received through the Baylis Medical Capstone Design Award and the Canadian Posture & Seating Centre Scholarship. Special thanks to Alex Magdanz, Chris McClellan, Calvin Young, and Bryan Tripp for their expert guidance and mentorship throughout this project.

References :

[1] T. Kasai, T. Isayama, and M. Sekido, "Squamous cell carcinoma arising from an ischial pressure ulcer initially suspected to be necrotizing soft tissue infection: A case report," Journal of Tissue Viability, vol. 30, no. 4, pp. 621–625, 2021.
[2] "Pressure injury and Spinal Cord Injury," Pressure Injury Toolkit For Spinal Cord Injury and Spina Bifida, https://aci.health.nsw.gov.au/networks/spinal-cord-injury/pi-toolkit/pressure-injury-in-spinal-cord-injury (accessed Mar. 18, 2024).
[3] D. Fogelberg, M. Atkins, E. Blanche, M. Carlson, and F. Clark, "Decisions and dilemmas in everyday life: Daily use of wheelchairs by individuals with spinal cord injury and the impact on pressure ulcer risk," Topics in spinal cord injury rehabilitation, vol. 15, no. 2, pp. 16–32, 2009.
[4] T. V. Boyko, M. T. Longaker, and G. P. Yang, "Review of the current management of pressure ulcers," Advances in Wound Care, vol. 7, no. 2, pp. 57–67, Feb. 2018. doi:10.1089/wound.2016.0697
[5] S. Pritchard, H. Cardoza, and S. Stupalo, "Biomedical Stakeholder Cafe", In-Person Meeting (October 4, 2023).
[6] J. Howcroft, E. Boulanger, and I. Ahmed-Fazal, "Biomedical Stakeholder Cafe", In-Person Meeting (October 3, 2023).
[7] FDA, "Maude adverse event report: ROHO, Inc.. ROHO® quadtro select® high profile® cushion; wheelchair cushion," U.S. Food & Drug Administration, https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/detail.cfm?mdrfoi__id=17720290&pc=KIC&device_sequence_no=1&fbclid=IwAR21U81hrDNswQgHKGRolxGYwspg-ZUnp_UgKcvt332IKuXMN7OR0GMZb-U (accessed Nov. 9, 2023).