Loop One: A DIY design for managing wheelchair thermal comfort

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Abstract–***Loop One is an open-source design that aims to alleviate thermal discomfort among wheelchair users. With water looping through the wheelchair's cushion and a Peltier module pumping heat in the required direction, the user can control whether their chair should warm up or cool down. This is important as regulating the seat temperature can minimise the risk of pressure sores.***

I. INTRODUCTION

Several groups of wheelchair users face challenges with temperature regulation. Reduced sweating ability can be observed in patients of cerebral palsy [10] as well as multiple sclerosis [11]. Wheelchair users with complete lesions also face challenges with thermoregulation, as they cannot sweat below the lesion point [6-8], resulting in decreased surface area from which to sweat (and thus cool down) [9].

Maintaining contact with the wheelchair seat for a long time results in increased temperature and humidity between the user's skin and the seat surface, raising skin temperature [3, 4]. This effect is exacerbated for users who require significant support from their seat, as this means the area of surface contact is greater. Increased skin temperatures result in higher skin tissue metabolism and thus worsen susceptibility to pressure ulcers. One study indicates that a 1°C increase in skin temperature increases tissue metabolism by 10% [3].

Pressure ulcers are a skin wound that can appear as a slight discoloration if mild, or a deep wound exposing muscle and bone at their worst. These ulcers can be formed as pressure is applied to the skin over a period of time — the greater the amount of pressure or the duration of time, the higher the risk. These ulcers are important to prevent as beyond the discomfort, they can become infected and are very dangerous to elderly population in care homes [1, 13]. To relieve the built up pressure, wheelchair users are often advised to shift their weight around in regular time intervals and even transfer out of their wheelchair when possible. However, the latter is not practical for wheelchair users at work, school, or in outdoor settings. In fact, 95% of wheelchair users with a spinal cord injury (SCI) in the rehab sector develop a pressure injury in their lifetimes [15].

This paper presents Loop One, an open-source, DIY cooling design that gives wheelchair users control of their seat temperature. Developing solutions that reduce skin temperature, particularly in areas of vulnerability or high pressure is important in reducing hospitalisation due to pressure ulcers as they are expensive to treat and can lead to prolonged hospitalisation times [2,5].

II. RELATED WORK

Assistive technology related to a wheelchair user's thermal comfort is limited. Beyond passively ventilated cushions that allow for passive ventilation we have identified two products that aim to alleviate thermal discomfort.

WheelAir uses battery-powered fans and ducts to route air to the user's back through the backrest. It costs upwards of $650 based on the wheelchair type.

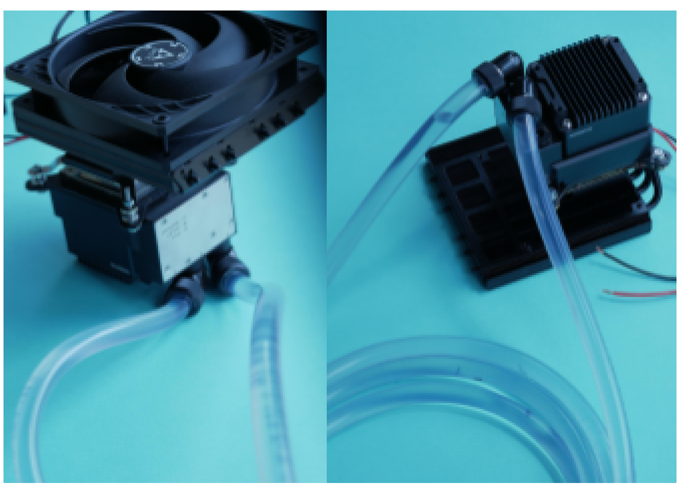
CryoFluid [14] by Sunrise Medical is a bladder within the cushion that contains a bead-based material which absorbs heat from the body until the beads melt completely. It lasts for a maximum of 8 hours and then sets again at room temperature. A cushion including this technology costs $617.

III. A FIRST PROTOTYPE

Loop One was derived from a clear need for a thermal comfort solution that is detached from global AT supply chains and is more financially accessible and customizable. The concept is that within the seat's cushion, water courses through a flexible tubing loop, cooling or warming the user.

It features off-the-shelf PC water cooling equipment such as tubing, a water block, a pump, a reservoir and an in-line flow and temperature sensor. The water block is attached to a Peltier thermoelectric cooler (TEC) module, the TEC12706, which, depending on the polarity of the DC voltage supplied, pumps heat in the desired direction. On the other side of the TEC are a low-profile PC heatsink and fan to maintain a significant temperature difference between the sides and prevent heat backflow. While the project has a recommended bill of materials, the open-source customisable nature of Loop allows for flexible part selection based on local availability.

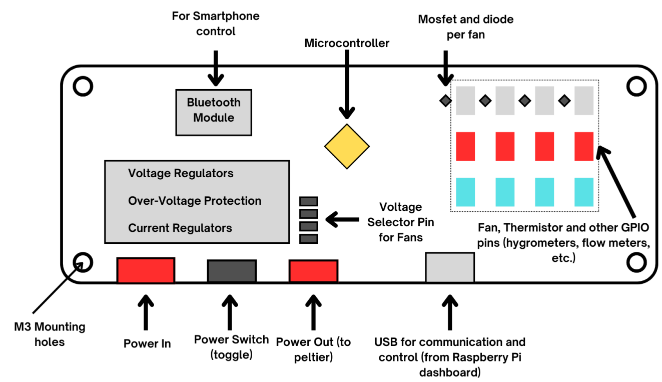
The current prototype consists of the complete loop made of a 3 metre tube (10mm ID, 13mm OD), an all-in-one 17W PWM pump/water block/reservoir combo by Barrow, a Peltier TEC12706 module, and for the air cooler an Alpenfohn Black Ridge heatsink is used because of its strong cooling performance-to-size ratio. The TEC, pump and heatsink fan are powered from a bench power supply and varying current or voltage changes the TEC's performance. Switching voltage polarity makes the TEC transfer heat in the opposite direction.



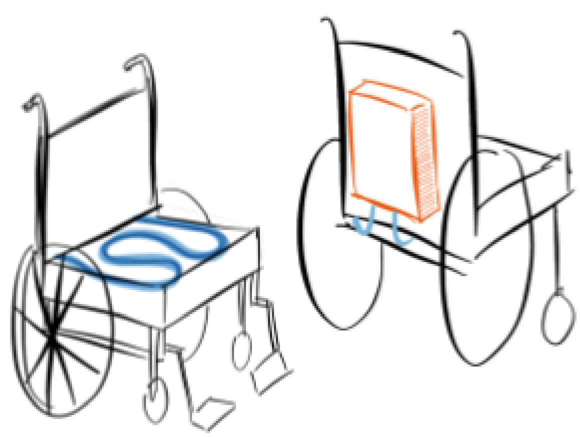
IV. ENVISAGED NEXT PROTOTYPE ITERATION

Currently, a microcontroller breadboard iteration is being designed. This serves to provide methods of controlling pump and fan speeds, and controlling the power sent to the TEC. For the latter, two methods will be examined, MOSFET and brushed ESC control, with a switching frequency of about 1kHz, which seems to be optimal based on initial research. Additionally, a microcontroller can measure readings from the inline thermistor and flow metre to be added at the input of the pump (after the water has travelled the loop). Temperature readings can be used for safety cutoff measures as well as controlling the power of the TEC. Similarly, the flow rate data can be used to confirm that the tubing is not squeezed under the user's weight. If the tubing is not placed high enough in the cushion, the user will not feel its effects, but if placed too high, it might get squeezed, blocking the water flow and working against the pump.

While space conservation is not a significant concern for the envisioned product, a transition from breadboard to PCB-based electronics still offers several benefits: using locking connectors (e.g. JST-XA) between components and the PCB can minimise the risk of loose or disconnected cables from bumpy rides; easier assembly by users since many connections are already completed (traces on the PCB); streamlined troubleshooting process as many connections are robust and areas susceptible to user error are minimised; PCB offers a professional look and allows a smaller enclosure, particularly important for the social aspect of Loop One's use. This is what the PCB might look like:



With the PCB dimensions finalised, a 3D printable backpack-style enclosure can be designed that holds all the water-cooling components apart from the tubing. Placing the PCB and all other electronics above the pump and tubing connections, along with creating sealed (3D printed TPU gaskets) dividers between water and electronics will make for a safer design. Additionally, options to seal the device from outdoor elements (e.g. rain) and offer mounting options for real backpacks on top of the enclosure should improve the usability of the device. This is what Loop One could look like:



V. RESPONSIBLE INNOVATION

If Loop can successfully allow wheelchair users to control the temperature of their seat and eliminate overheating or feeling cold it can significantly impact users' daily lives. If the temperature difference proves to reduce the risk of pressure ulcers, Loop can be a life-changing solution for patients.

Loop uses off-the-shelf PC water cooling components for most of its assembly, so that users can easily replace components with the same or locally available replacements. Custom components include 3D printed parts and the PCB aimed to be developed at this summer school. The schematic for an Arduino and breadboard/prototyping board is still provided for users who wish to follow that route. 3D printed parts are designed with consumer FDM in mind, with no overhangs needing supports (beyond built-in supports) so that they can be commissioned from a service like PCBWay or an Etsy 3D printing provider if users cannot print them.

VI. AUTHOR BIO

I am a Computer Science PhD student (UCL) with a bioengineering background (MEng, Imperial College London) working on making assistive technology more accessible through DIY, open-source designs.

I'm skilled in Python and 3D CAD, and passionate about additive manufacturing, particularly FDM 3D printing. I can prototype with microcontrollers and solder confidently but PCB design skills will improve my prototypes and bring them closer to realisation. Beyond Loop, my PhD involves other DIY or open-source wheelchair AT that will benefit from PCB skills [16, 17].

VII. ACKNOWLEDGEMENTS

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