Heat Pixels: Somaesthetic Design of Smart Fabrics

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Abstract*—*Integrating heat generating elements into wearable fabrics has a potential to address various therapeutic needs many people face as a mean for relieving muscle-related pains to name one application. From the HCI perspective it also opens the door for a tangible interaction modality that utilizes our senses through skin receptors, which can work in a bi-directional manner: first, as an active element that emits heat to the body or extracts (a sensation of cold), and secondly as a passive element that reacts to body temperature and changes properties of the cloth we wear for instance. However, there are many challenges for using heat on the go: most electric devices can only generate heat (and not extract), being energetically inefficient, simply wiring resistors through fabric has the risk to easily fail once a circuit is broken under bending/stretching - creating a cumbersome cloth to wear, or providing enough energy to drive the heat exchange process. This project tries to build a scalable infrastructure based on solid-state heat devices using the Peltier effect as heat junctions to integrate into fabrics, first as independent off-the-shelf elements and later on embedding varying density junctions as part of the fabric itself.

I. Introduction & Background

Heat and cold are used extensively in our daily lives for various purposes, either being just creating a pleasant feeling of warmth or for actual treatment of pain, inflammation, or muscle spasms. Although such practices date back to ancient times, they didn't develop to take advantage of technology improvements and integrate it with the cloths we wear for example.

The benefits of being able to produce directed heat or cold at desired locations and instants of time are well established [3] but can also be questioned at the extreme (like Moxibustion [4]).

Certain limitations had prevented heat from being widely adopted into fabrics. An energy source is needed to transfer heat from point-to-point, requiring people to either be connected to a wall outlet or carry a battery, which limit the time and intensity that can be achieved. Producing heat isn't efficient when it comes to controlled systems, mainly electrical, not to mention the opposite, of extracting heat for the purpose of generating cold, aka heat pump. They all rely on specific ambient conditions in order to function at desired set points and produce a temperature difference. In addition, humans vary and even our body vary in response to heat sources - the sensation one would assume pleasant and sustainable differs from one to another [5][6].

Our goal is to develop an open and scalable, model system that would allow one to replicate directed heat (or cold) generation and embed them within fabrics for daily usage, therefore the term heat-pixels.

II. Related Work

Somaesthetic design [2][3][7] is an approach that aims to increasing the somatic awareness by better understanding our body perception.

The focus on the aesthetic of heat in this context and various design objects was explored deeply in [8] and into a more specific application by [1] and [9]. Their main motivation was creating a stimuli for increased awareness, but not for treatment purposes or a combined experiences.

The lack of a flexible, scalable, multi-purpose system that allows heat-interaction research (also cold) and serving as an infrastructure for integration with fabrics was the driving force for the following design project proposal.

III. Imagined or Existing Prototype Sketches/Drawings/Photos

A. Existing Prototype

The current prototype represents the first step for evaluating the concept, before progressing toward minimization and embedding into fabrics. It's intend use is testing multiple heat elements working in conjunction around different body parts and producing varying signals (heat/cold intensity) with a remote control.

Figure 1 - Figure 4 showcase the various components that were used for a low-fidelity prototype. The main control unit is based on Arduino Uno R3 with a sensor shield attached on top for ease of connectivity and since the logic is exposed through a serial/Bluetooth remote interface, the microcontroller need not be too sophisticated. A multi-channel MOSFET board is used for driving the Peltier heat elements and connected on the other end to an external DC power supply providing 5V output, which suffices to produce enough heat through the voltage range. The Peltier elements themselves are of different dimensions, two are 15x15 mm and the remaining two are 20x20 mm, both types having 127 poles within the case. The elements are enclosed within a machine sewed Cordura 500D fabric for better heat isolation and durability. One side of the Peltier elements faces the human skin, while the other is covered with a heat conductive layer of a larger surface area to increase the element's performance at producing or extracting heat.

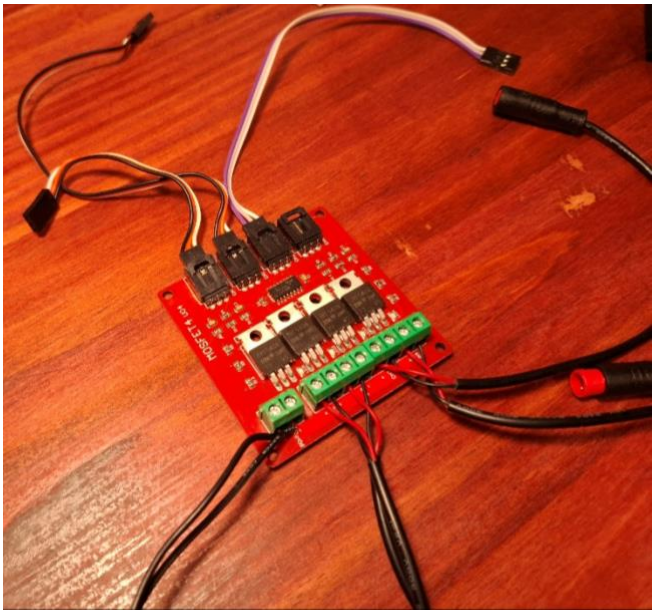

Figure 1 - 4-channel MOSFET to drive 4 Peltier heat elements independently.

The code inside the Arduino board exposed an interface that allows one to control each heat element independently and specify the heat intensity to produce, either with a fixed value on every call or requesting a periodic (sine based) change. The same interface is available via a wired serial connection or also through Bluetooth connection to operate from a mobile or computer remotely.

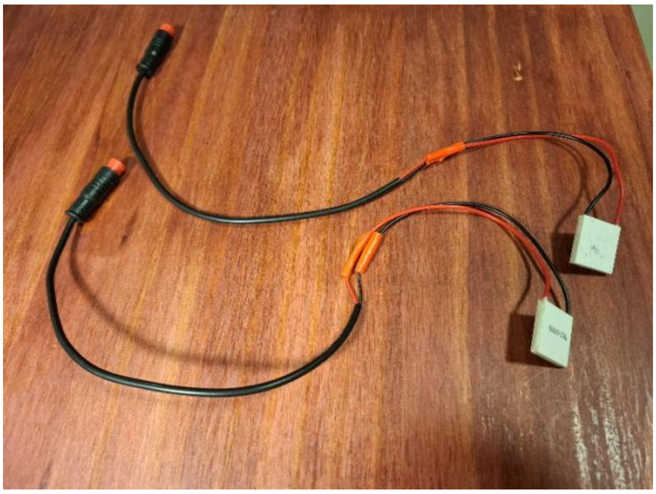

Figure 2 - Soldered Peltier elements with extender cables to reach distant part of the body from the control unit.

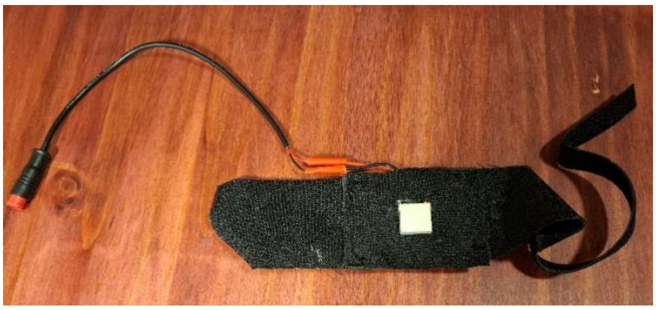

Figure 3 - Peltier element inserted into a case with Velcro strap to fix around specific parts of the body (arm, leg etc.).

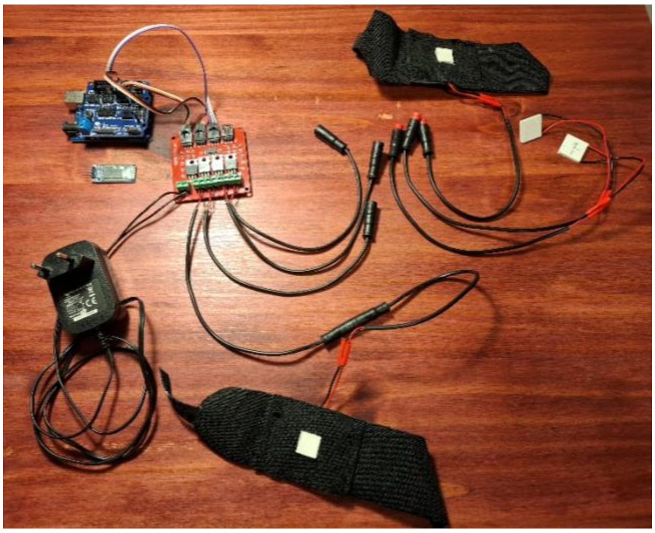

Figure 4 - Whole system consisting of an Arduino Uno + sensor shield, 4-channel MOSFET, commercial Peltier elements with extender cables, external 5V DC power supply, Bluetooth transceiver for remote control.

B. *Future Design & Scalability*

There are certain goals to achieve as the prototype will mature. First, supporting more channels/heat elements per the same microcontroller. This can be accomplished through a 16-channel PWM driver such as the PCA9685. In addition, it would be great to utilize an H-bridge functionality to generate both heat and cold without the need to actively change polarity of the connector.

The Peltier elements themselves are small enough, but still having rigid structure that might prevent them from fitting every usage on the body, therefore the ability to disassemble an element and construct smaller clusters of junctions would be better. This opens the opportunity to later embed these clusters within fabrics more easily, while the ceramic enclosure needs to be thought of a replacement for heat capacitance.

The complexity of the system can be reduced by designing a PCB that will incorporate the microcontroller, multi-channel PWM source, MOSFETs and battery connector for easy swapping energy source.

As a final thought and more challenging one, the actual wiring of the Peltier elements can be embedded within the fabric, having a single point of connection to the control unit.

IV. Responsible Innovation

The goals behind the design of the system are multi-fold: creating an open research infrastructure for the study of heat/cold generation and interaction with the human body, a unit which is agnostic to the actual design/placement of the heat elements within the fabric, providing a flexible solution for therapists and users at home willing to experience with heat treatment, or designers looking to incorporate materials that adapt to heat and the environment.

V. Author Bio(s) / Experiences

Mordechai Botrashvily is currently a master student in the field of HCI at Reichman University, focusing on smart materials and integrating heat sources into textiles with the aim of expanding this research further. His prior experience includes software development for more than 10 years, mostly on abstract systems and less of physical and embedded artifacts. The motivation to produce smart-heat fabrics comes from a multi-disciplinary background in physics (B.Sc. & M.Sc.), sports (former athlete and instructor) and physical therapy, understanding the necessities athletes face during their practice sessions, but also what is required to adapt high-end solutions for ordinary users. The most current co-work involving heat in our lab is the walking mat [1] that was presented and demonstrated at CHI 2024 and 2025.

VI. Acknowledgements

I'd like to acknowledge Prof. Oren Zuckerman from the media lab for the opportunity to take this heat endeavour and explore the use cases beyond just a physical phenomena. Also thank Mr. Zvika Markfeld for the professional guidance into the world of embedded and robotics, and the other members of the lab for their support along the way, through soldering, picking the right materials and so forth.

VII. Refernces

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