University of Minnesota Wearable Technology Lab

Designing Controllable Heated Garments for Mediating Personal Microclimate

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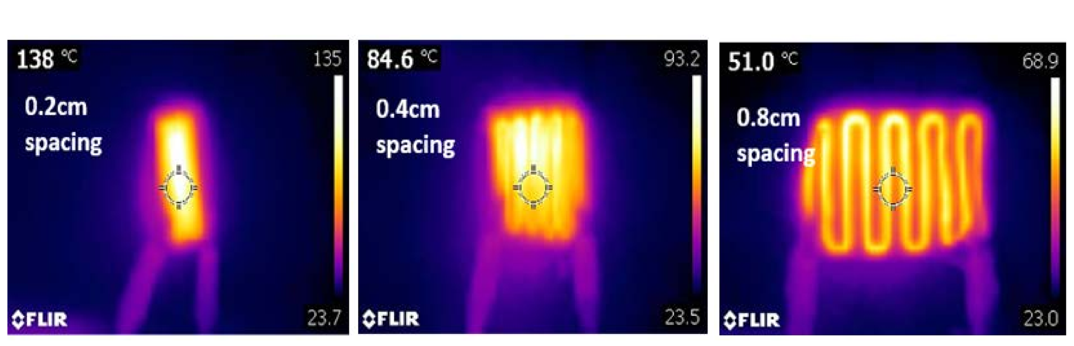
Introduction

Applied, on-body thermal systems have a variety of potential benefits. For instance, heat is often used in medical treatments, and for improved comfort in cold environments. Heating the body (the microclimate) can also reduce energy expenditure and waste in the macroclimate (rooms and spaces). However, human experience of thermal comfort is driven by the sensory experience of the periphery (hands, feet, face); therefore, heat must be delivered to these zones without affecting comfort. Beyond functional effects, a change in microclimate temperature might act as a stimulus for a persuasive technology interface. To explore these future possibilities, an on-body heating solution was developed in the form of a heated extendable cuff [1][2]. Current research includes improving the garment design and developing integrated temperature feedback control to prepare for future user-controlled microclimate studies.

Thermal Textile Development

Heat-producing textiles are made by sewing conductive fiber to the surface of a fabric using a pattern stitching machine. Sewing allows the placement of the heat element (conductive fiber) to be customized.

Heating textiles were developed and tested to determine the best-fit base textile, thickness of heating element, spacing of heating element, and effects of different insulation layers (Figs 1 and 2).



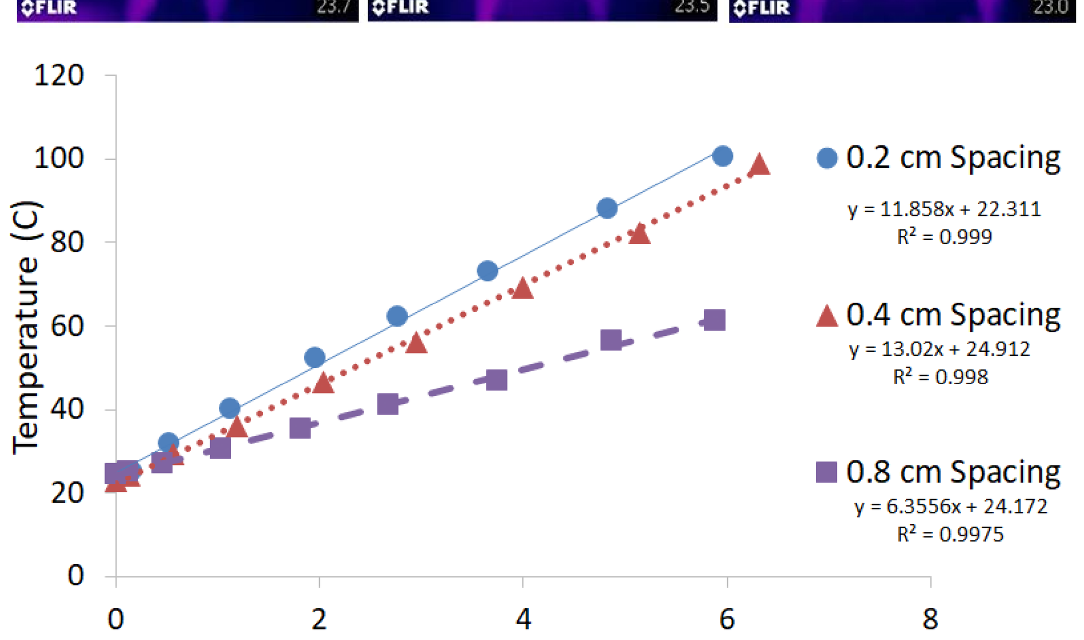


Figure 1: Actuator swatches showing variable trace spacing (top) and corresponding performance (bottom) [1].

Figure 2: Actuator swatches showing (a) variable trace thickness (b), trace spacing (c), and fabric substrate properties [1].

Garment Design

A hand and wrist garment (Figs 3 and 5) was developed to test the effect of heating on measured and perceived microclimate. The garment heats two zones: 1) dorsal/ventral hand; 2) dorsal/ventral wrist. Glove temperatures of 35°C, 37.5°C, and 40°C were tested in cool and warm-temperature thermal chambers. Results (Figs 4 and 6) show heating effects are strongly influenced by variability in physiology. A closed-loop system (Fig 7) is now under development to control for surface temperature across subjects.

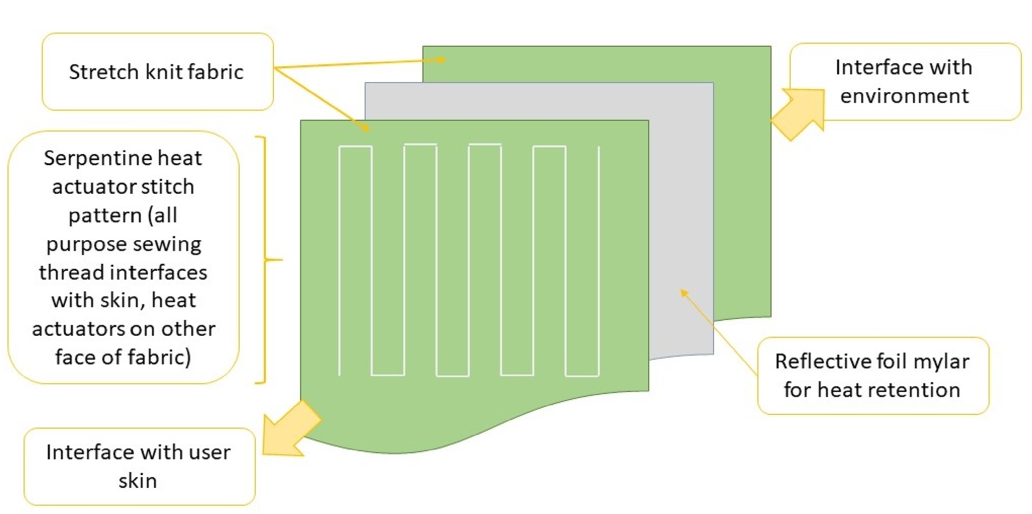


Figure 3: Garment fabric layers schematic [2].

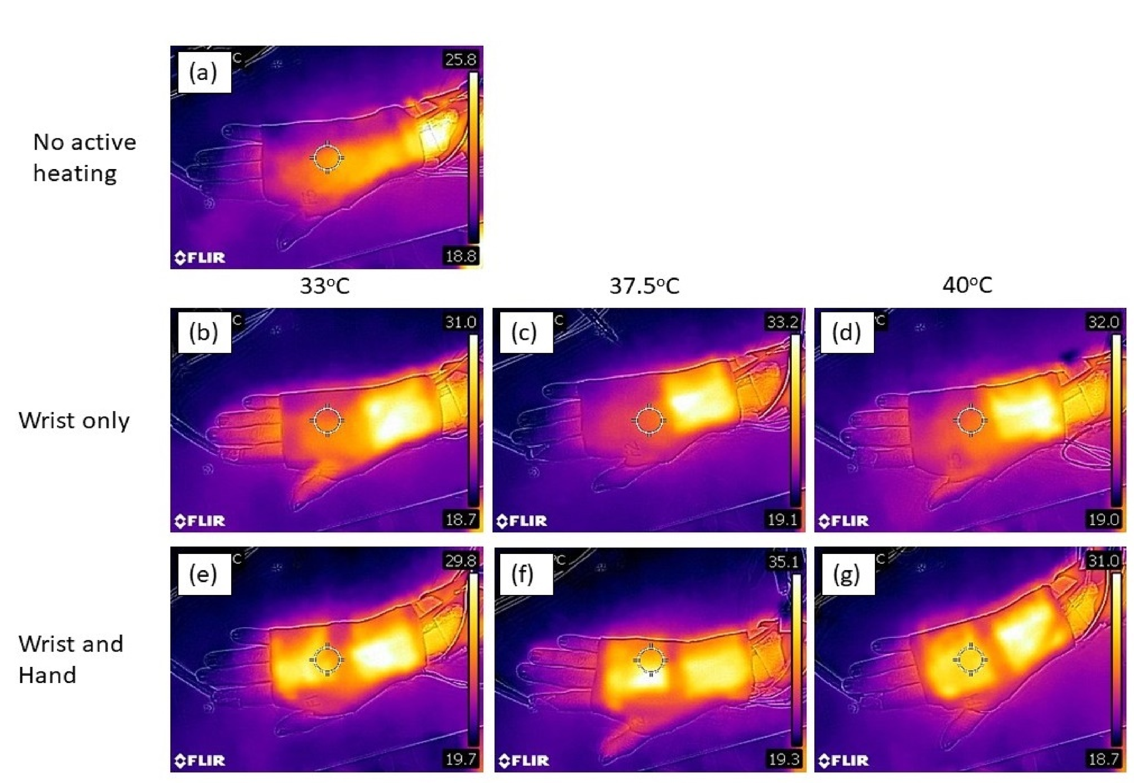


Figure 4: Thermal images for one participant during each test condition. (a) No active heating, (b)-(d) wrist only heat, (e)-(g) wrist and hand heating. Scale values in vertical bar, image right [1].

Figure 5: Garment Design [2].

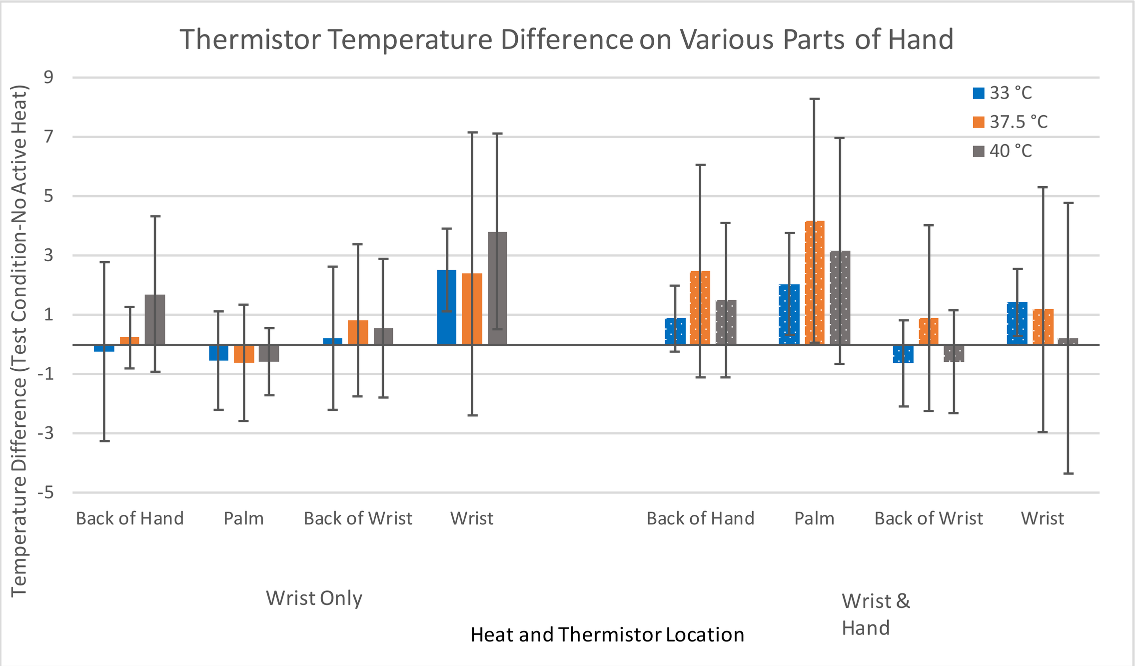


Figure 6: Averaged thermistor temperature difference on various parts of the hand compared to no-heating condition [2].

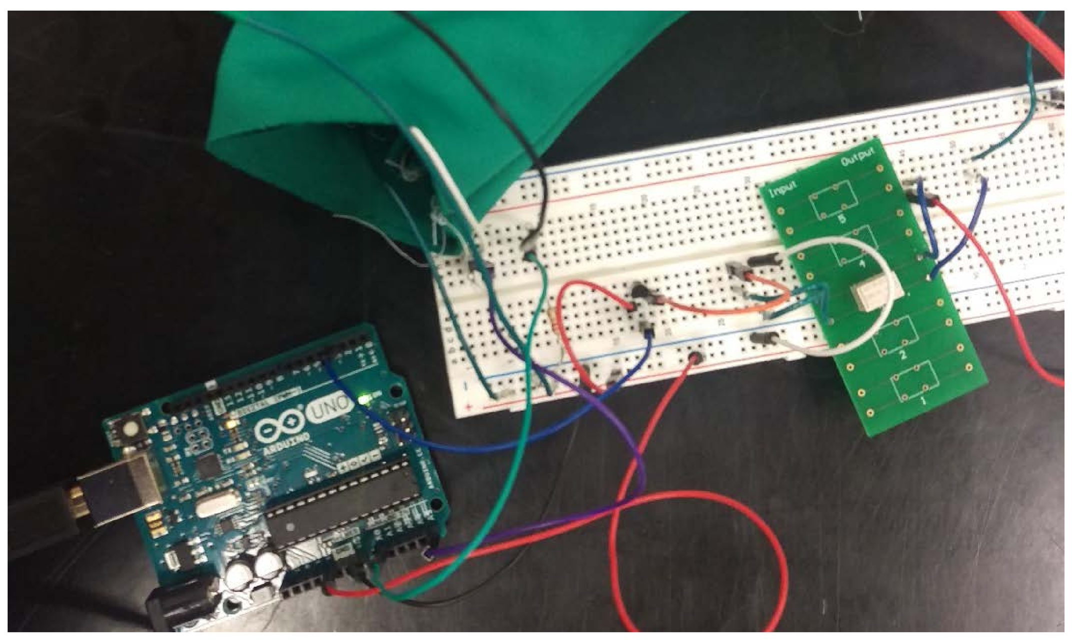


Figure 7: Feedback system using a thermistor input and Arduino Uno® microcontroller to control resistive heating.

References

[1] E. Foo, N. R. Gagliardi, N. Schleif, and L. E. Dunne, “Toward the Development of Customizable Textile-integrated Thermal Actuators,” in Proceedings of UbiComp/ISWC 2017, pp. 29–32.

[2] Gagliardi, N. R., E. Foo, E. Dupler, S. Ozbek, and L. E. Dunne, “Design of a Stitched Textile-Based Thermal Actuator Garment to Attenuate Peripheral Microclimate Experience,” in Proceedings of the 2018 in Proceedings of the Design of Medical Devices Conference, 2018.

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