Thesis Project Portfolio

A 2-Dimensional mm-Scale Network-on-Textiles (kNOTs) for Wearable Computing with Direct Die-to-Yarn Integration of 0.6×2.15mm^2 SoC and bySPI Chiplets

(Technical Report)

Unwearables: A Multilevel Perspective on the Abandonment of Wearable Electronic Devices in Healthcare Applications

(STS Research Paper)

An Undergraduate Thesis

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Braden E. Desman
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Department of Electrical and Computer Engineering

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Sociotechnical Synthesis

(Executive Summary)

Fabrics of the Future: Designing Long-Term Health Monitoring Systems Built on a Textile Computing Platform

"They wanted simple, clear technological solutions. But we technological objects have nothing technological about us."
– Bruno Latour, *Aramis, or the Love of Technology*, pp. 296

In-fabric computers are poised to revolutionize healthcare by integrating physiological sensors, batteries, and microchips into textiles that look and feel like conventional cloth while also possessing health-related inferencing capabilities. For my technical project, my team and I demonstrated an in-fabric computer prototype by designing a communication chip and a system-on-a-chip (SoC) and integrating them onto a fabric swatch as depicted in Figure 1. When I was in STS 4500, I happened to read an article that showed that more than 50% of wearable device owners abandon their device just weeks after purchase. This statistic set off a cacophony of mental alarm bells and inspired me to devote my STS research project to improving our understanding of this wearable abandonment phenomenon. Specifically, my STS research evaluates how niche-level sociotechnical factors, institutional-level rules and norms, and global events conspire to promote or discourage the long-term adoption of wearable health-monitoring technologies.

Figure 1. My team's networking chip attached to a fabric and positioned next to a dime.

My technical project was conducted as part of my role in Dr. Benton Calhoun's Robust Low-Power VLSI lab for an IARPA program called SMART ePANTS. My team's deliverable was a two-dimensional network of SoCs and communication chips that boasts a dramatically reduced per-chip area-footprint, low-power operation, and support for an arbitrarily scalable number of components. Additionally, our collaborators at Nautilus Defense improve upon existing textile-integration methods with their direct die-to-yarn embroidery technique. To further address in-textile challenges, my team adds features like dynamically reconfigurable input/output pads, error-resilient global bootup, and inter-chip time synchronization. Collectively, these features enable our chips to operate as a cohesive data collection system, capable of determining the temporal relationship between data from different chips, despite having asynchronous clocks. The scalable communication protocol of our design enables our SoCs to control a large network of sensors and memories without increasing the size of the individual components. By keeping each individual chip as small as possible (currently 0.6 mm x 2.15 mm), our smart textile is able to retain the look and feel of a conventional garment while possessing novel computational capabilities.

My STS research seeks to improve our understanding of why wearable devices have such high abandonment rates. Specifically, I use a multilevel perspective to evaluate wearable devices as a health monitoring system in terms of niche-level factors that promote emerging technologies, regime-level factors that stabilize systems, and landscape-level factors that create destabilizing conditions. I find that the technological niche is replete with competing visions for the future of wearable health monitoring systems such as my team's fabric computing paradigm and head-mounted devices. These technologies receive increasing attention and funding due to global public health crises, which constitute landscape-level events. Although factors at both the niche and landscape level promote the long-term viability of wearable devices, I find that the existing network of regime-level norms and rules are insufficient to create lasting stability. In particular, entrenched cognitive routines among healthcare providers and patients alike discourage the use of technologies in new form-factors. I conclude that the abundant innovation in wearable technology must be complemented by commensurate social innovation, particularly in terms of behavioral norms and cognitive routines that promote long-term use.

I encountered unexpected feelings of cognitive dissonance this semester as I simultaneously participated in STS and solid-state circuits research. Although my technical sponsor's objective is to design smart garments for human use, they have neither required nor suggested that we consider human factors beyond basic comfort. Further, despite being funded by a government intelligence agency whose activities presumably include espionage, there is little program-wide consideration of privacy and ethics. The parochial notion that a novel, human-facing technology can be developed without regard to the sociotechnical dimensions of the system contradicts virtually everything I have learned in STS. Further, this approach shares alarming similarities with that of *Aramis, or the Love of Technology*. Let us not forget Latour's lesson: there is no such thing as *just* a technological solution. To not consider the ethicality of smart garments that possess intelligence-gathering capabilities would be to set the stage for sociotechnical dysfunction and to embrace technological determinism. As I gain experience and influence as a researcher, I intend to adopt the language of moral foundations theory as developed in *The Righteous Mind* to lead discussions on the ethical dimensions of our research, to persuade my peers to make design choices that promote the responsible use of our technology, and to encourage my community to embrace the discourse of design.