Identifying Challenges of Fabricating E-textile Garments Via a Case Study

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Keywords: E-textiles, smart clothing, wearable technology, garment-integrated technologies, manufacturing.

Introduction: Integration of electronic components and circuits into clothing is a key requirement of garment-integrated technologies, especially when the electronics need to be distributed over the clothing surface, which allows power and networking to be localized, placement of electronics to be more broadly distributed, and reduces the necessity of using and managing many body-worn units (Dunne, Simon, & Gioberto, 2015). The disparity in material properties between electronics (primarily hard goods) and textiles (primarily soft goods), as well as differences in their manufacturing processes, exacerbate the difficulty of scalable integration of electronics into clothing. Though many researchers have developed example applications of e-textiles in fashion and other artistic applications (Buechley & Eisenberg, 2009), these garments often use hand-sewing methods that are not efficiently replicable in the industrial setting. In this paper, the scalable manufacturing technique we have developed that facilitates surface-mount soldering of discrete components and ICs directly onto fabric surfaces is translated into garment form as an intermediate step toward full-scale manufacturing. Through the fabrication process of an example garment, variables relevant to manufacturing garment-integrated electronics are discovered and discussed.

Figure 1. Motion responsive visual display garment, a) final garment, b) Traces and layout for LED display on garment.

Method: The case study design used here is a sensor-controlled smart shirt, with embedded inertial sensing, microcontroller, power source, and LED display (Figure 1). The method described in (Berglund, Duvall, Simon, & Dunne, 2015) and (Molla et al., 2017) uses an Industrial Pattern Stitching Machine to stitch conductive traces onto a fabric surface in a 2D pattern and has been used here for LED integration and to create interconnects between spatially-distributed components. Figure 2 illustrates the production process used for creating the garment.

Figure 2. Diagram of the production process.

As in traditional garment manufacturing, a garment pattern was created and plotted on fabric pieces. Since we used three different spatially-distributed units in the system (i.e. LED matrix, Arduino microcontroller, and accelerometer), several conductive traces were needed to make electrical connections across the garment. The trace layout was established during the pattern development stage, and a final design was selected that had the minimum number of trace crossings to avoid potential shorting and minimize labor. A custom-designed stitch layout for the LED display and accelerometer circuit was produced using the Brother pattern stitch software, and LEDs were attached using the surface-mount reflow soldering process. A three-axis accelerometer was placed on the right cuff of the shirt, and an Arduino pro mini microcontroller and a battery were attached at the back of the shirt. These were attached using stitched through-hole techniques similar to Buechley and Eisenberg (2009). Traces connecting distributed components were sewn manually using a typical Lock Stitch machine. The remainder of the garment was sewn, loose traces were connected, and trace crossings were insulated.

Results and Discussion: The addressable LED packages used here require 4 pin connections. In a serial layout, we routed power and ground rails around the edges of a serpentine pattern. Input and Output traces were daisy-chained, and a float stitch was laid using the pattern stitcher (and subsequently clipped prior to soldering to isolate the traces). The lockstitch structure used creates traces on only one side of the fabric, therefore traces must be insulated in locations where traces cross. A satin stitch was used where traces crossed, by floating one trace over another already stitched trace. To isolate crossing traces, we lifted the float and applied fabric paint to the lower trace. However, in the future it may be feasible to facilitate trace crossing by allowing traces to pass to the other side of the fabric (using a 2-layer circuit layout).

We found that long or tight (tension) traces were more likely to break compared to shorter traces with proper tension. Applying tension to the fabric while stitching (all directions) resulted in better, more uniform traces. Where parts of a trace were joined (e.g. between the pattern stitched traces and lockstitch traces) backtacking was used to create a better connection by increasing the conductive surface area. Backtacking was also used as reinforcement at corners, transition points, and crossing garment seams (e.g. armscye). Joints were soldered to make an even stronger connection compared to contact-only connections, which have lower conductivity.

We faced several challenges while troubleshooting the electronic system in the garment. Since all the LEDs were connected using serial communication, one single weak or faulty connection might cause the circuit to stop functioning properly. We used in-line quality checks through visual inspection, applied power (to check LEDs), resistance measurement (to check for short circuits), and by attaching other system components. However, while assembling the garment, some of the connections became weak or even broke due to handling of the electronic components, pointing to the need for continual quality checks. Further, quality checks became progressively more difficult to perform as the garment was assembled. Future studies should include attention to development of comprehensive performance testing of the garment system.

Conclusion and Future Work: This case study served to investigate the translation of a technique for fabricating surface-mounting electronic components using stitched traces and reflow soldering techniques toward the goal of full-scale cut-and-sew manufacturing. Variables that influence the fabrication and quality assurance process of e-textile garments have been identified and discussed. Future studies should involve evaluating the variables of more complicated textile circuits (more components and traces) and the possibility of 2-layer circuit development, which would minimize the number of trace crossings. This would contribute to a holistic view of the challenges involved in the e-textile manufacturing process.

Acknowledgments: This work was supported by the National Science Foundation under grant # #CNS-1253581.

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