Handcrafting Textile Interfaces from A Kit-of-No-Parts

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ABSTRACT
This paper explores the idea of handcrafted electronics. We introduce a kit-of-no-parts approach to building electronics from a diverse palette of craft materials, which we argue is more personal, understandable and accessible than the construction of technology from a kit of pre-determined components. We illustrate our approach by describing the design, construction, and dissemination of a collection of textile sensors, and detailing a website and a series of workshops through which we share our approach.

Author Keywords
Craft materials, construction kits, E-textiles, DIY, design methodology, sensors, personalization, documentation, workshops

ACM Classification Keywords
B.m. Hardware: Miscellaneous

General Terms
Theory

INTRODUCTION
The materials and tools we use as well as the approaches we take to design, prototype and build technology greatly influence how we think about technology, the collection of people who think about technology, and the look and feel of the technology itself.

Construction kits make making technology easier. As systems of modular parts they lower the entry bar to science, engineering and technology disciplines. Their modularity allows for them to be assembled and almost as easily disassembled in order to iterate through a series of designs. But this modularity comes at the cost of constraint. The parts of a construction kit function inside modular systems and as such the designs realized with these kits are limited.

While constructions kits enable more of us to make and explore technology they ultimately constrain what we build and how we think. Craft on the other hand is associated with building as a form of personal expression. Craft materials are more often praised for their aesthetic, decorative and material qualities, than their ability to convey technological concepts. Building artifacts from craft materials is more like drawing from a palette of raw materials allowing for rich design explorations that construction kits of pre-manufactured parts cannot offer.

Building electronics from craft materials provides novel pathways for understanding technology because it requires that the builder understand the electrical properties of the materials involved. Understanding electronics at the material level enables us to build electronics from a greater range of materials than are currently included in traditional electronics kits. This understanding of materials will help us broaden our approach to building electronics and impact the kinds of humans-computer interfaces we build. Craft materials and techniques support us in understanding technology at a more intimate level from which we can personalize technology to better suit our individual needs and desires.

The following three aspects summarize our approach to handcrafting technology and helping others do the same:

(1) Personalization: leveraging the open palette craft materials to create unique and personal artifacts.

(2) Transparency: designing artifacts whose function can be determined from their form.

(3) Skills transfer: using craft materials to connect existing knowledge and skills to technology creation and customization.

More specifically, our work focuses on the application of craft techniques and the inclusion of craft materials and tools to create interface technology in the form of textile sensors. Previous work in E-Textiles demonstrates the affordances of building wearable interfaces from conductive fabrics and threads and the new solutions that can arise from this material exploration [9]. The aesthetic, expressive and cultural qualities of textiles play significant rolls in the process of combining textiles and electronics [10]. They inform the process and are communicated through the results. Besides the

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combination of electronics with textiles the seamless integration of digital computation and physical materials in architecture [8] is another approach that lends itself to crafting technology.

In the remainder of the paper we explain the design and construction of our textile sensors, introduce a website that we created to document and disseminate our work, and describe the series of workshops through which we engage with the community and propagate our approach to crafting interfaces. We conclude with the results of a post workshop questionnaire and reflect on how a kit-of-no-parts supports our design approach.

TEXTILE SENSORS

The expressive diversity of the materials we choose to employ in our designs stand in contrast to those of popular construction kits. The following textile sensors are constructed from a selection of electrically conductive fabrics, threads and yarns using sewing needles, pompom makers, crochet hooks and spool knitting machines.

In line with our approach to designing technology to be more understandable we chose to display functionality and integrate it in the aesthetics as much as possible so that the function of the sensors can be deduced from their form.

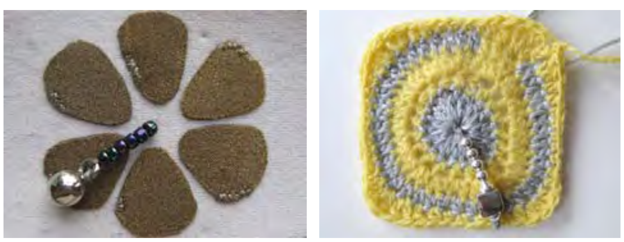

Figure 1) Tilt sensor (left) and crochet potentiometer (right).

The *fabric tilt sensor* shown in Figure 1 (left) is comprised of a free-swinging metal bead strung on a piece of conductive thread. The bead is surrounded by six petal shaped pieces of conductive fabric. Depending on the direction of inclination the metal bead will make electrical contact with different petals, enabling differentiation of six different positions of tilt. By replacing the discrete conductive petals with a resistive track, this sensor becomes a *crochet potentiometer*, like the one shown in Figure 1 (right).

Figure 2) Front (left) and back (right) of stroke sensor.

The *stitched stroke sensor* [Fig. 2] is made by stitching conductive threads through a base material to create a fur-like structure. On the back of the base material these threads are interconnected and belong to one of two contacts. When the hairs connected to one contact touch the hairs connected to the other contact the otherwise open switch is closed. By replacing the conductive thread with a more resistive thread, the stroke sensor responds to intensity of stroke.

Figures 3) Felted pompom pressure sensor with alligator clips connected to either side.

The *felt pressure sensor* is constructed by making a pompom from a blend of regular and resistive yarn and then felting it by running it through the washing machine [Fig. 3]. Felting the pompom gives it a unique squishy feel that makes it appealing to squeeze. When squeezed, the conductive fibers throughout the pompom make better electrical connections, lowering the resistance between any two points on the pompom’s surface.

The *knit stretch sensor* is a stretchy tube knit from the same resistive yarn as the pompom. When the yarn is stretched the twist of the yarn pressures the short conductive fibers together, improving the electrical contact between them and reducing resistance. Using a knitting machine to knit the yarn into a tubular structure creates a naturally stretchy knit structure. The bottom figures in Figure 4 show a close-up of this knit structure in its relaxed and stretched states.

Figure 4) Tubular knit stretch sensor (top), close-up views of relaxed (bottom left) and stretched (bottom right) states.

A complete overview of these sensors as well as details on their construction can be found on our website [7] in the *Sensors* category.

WEBSITE

In order to share our sensor designs we began giving workshops as well as documenting and publishing supporting materials online in the form of how-to instructions accompanied by photos and videos. In the summer of 2009 we launched a public website titled *How To Get What You Want* [7] where we continue to gather this documentation and present it in an organized structure. Access to information and resources are key aspects to our kit-of-no-parts approach and the website acts as a valuable reference library. Figure 5 shows a screenshot of the website.

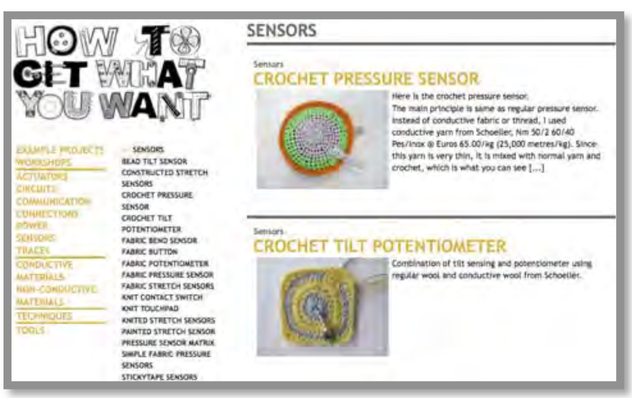

Figure 5) Screenshot of website.

The website is organized in categories which include *Example Projects*, *Solutions* (such as *Circuits*, *Connections* and *Sensors*), *Materials*, *Tools* and *Techniques*. The *Connections* category for example documents a variety of ways in which hard and soft conductive materials can be connected in permanent and non-permanent (pluggable) ways. The *Traces* category details different techniques for creating both stretchy and non-stretchy fabric trances. The *Sensors* category documents all of our sensors. Each sensor post includes step-by-step instructions, printable templates and links to retailers where users can purchase the materials and tools we used to make them. The *Conductive Materials* category contains information on all the conductive materials we have been able to get our hands on, with an emphasis on those that are soft, flexible and sewable.

WORKSHOPS

While the website has become a continuous platform for documenting and publishing our work, we initially started sharing our work through workshops [Fig.6]. Since 2008 we have held close to 20 workshops in almost as many countries, hosting between 5 to 20 participants and lasting anywhere from a few hours to a few days.

The aim of each of these workshops is to introduce participants to the prospect of personalizing interface technology through handcrafting textile sensors. Engaging them in hands-on material explorations that require them to acquire and exercise both craft and engineering skills. As workshop facilitators we see our role in conveying the underlying ideas of material experimentation and in supporting participants to conceive of and realize their own designs. Rather than try to teach participants how to recreate what we previously designed, we try to convey a style of working that emphasizes curiosity, creative use of materials, diligence in testing and patience in debugging.

Figure 6) Snapshot of a workshop environment.

Our workshops were inspired by the approach of several others, most notably the Scrapyard Challenge workshops [4] in which participants construct interactive projects from cast-off materials and junk. The LilyPad workshops [5] introduced teenagers to a toolkit with which they constructed E-textile designs while learning programming and electronics skills. The TeeBoard [3], Eduwear [1] and i*CATch [2] workshops and construction kits stand in contrast to our approach of emphasizing handcrafting. Each of these projects take a construction kit approach to teaching electronics and programming to children using textiles.

Workshop Structure

We start each workshop by introducing the materials and tools that have become part of our repertoire and will be available for use throughout the workshop. We introduce a selection of our sensor designs, as well as the materials and tools we use to construct them. We have found it useful to follow this introduction with a hands-on activity in which participants select a sensor from our collection and try to recreate it. Although we like to stress personalization in every activity it often proves too challenging to introduce it in this very first introductory activity and so simply re-creating a design is a good place to start. For workshops that last longer than three hours, we continue by introducing a topic that helps participants shape their individual designs. Themes have included *Wearable Sound Experiment*, *Piano T-Shirt* and *Bend, sew, touch, feel, read.* In the Piano T-Shirt workshop for example we provided cheap toy pianos and t-shirts. The pianos were gutted for their circuitry and components, and the piano keys were replaced with textile sensors. The sensors and the circuitry were mounted on t-shirts and other personal clothing items to make them wearable. Figure 9 (right) shows an example of a participant integrating textile sensors and circuitry to match the design of her t-shirt.

After participants have formulated an initial design sketch they present this to each other in order for them to collect feedback as well as for everyone to get an idea of what others are working on. After this first presentation of their idea, we help participants on an individual basis plan how they will realize their design. Part of our task here is to help participants develop designs that can be accomplished within the timeframe of the workshop. The rest of the workshop is spent realizing the designs. Although not everybody achieves the result they aimed for, it is rare that participants leave the workshop without some kind of functioning artifact. We wrap up the workshop with a quick show and tell where participants present their projects, explain their designs and convey their construction experience.

Throughout the workshops we make use of our website, pointing participants to detailed information that is published there. It has proven to be a valuable resource for participants during the workshop as well as a source for them to refer to for information after the workshop.

Participant Creations

To convey the nature of the workshop experiences, we now discuss several projects that were realized during the sessions. The projects we discuss are particularly nice examples of how craft materials and textiles in particular facilitate personalization.

The Human Violin is a performance piece realized by a group of seven participants. They designed and created a set of three costumes that allowed the performers to explore the connections between their bodies [Fig. 7]. Two of the costumes had a series of embroidered resistive stripes on them that wrapped around the limbs and torsos. The third costume had conductive patches adhered to it that acted as conductive sliders. All three performers were blindfolded during the performance so that the sensors replaced their senses. When the sliders came in contact with the resistive tracks pre-recorded sounds would play faster or slower, depending on the position along the resistive track, giving the blindfolded performers an idea of what body parts were touching. Their aim was to end the performance in a certain configuration that they had to achieve without being able to see one another.

Figure 7) Participant projects: The Human Violin (left), pressure sensitive toe sandals (right).

In a workshop *Bend, Sew, Feel, Read, Touch* two participants collaborated to make a pair of sandals with five pressure sensors embedded in the soles under the toes of each foot in [Fig. 7]. Five separate LEDs were mounted on the sandal's front strap to indicate through brightness how hard each toe was pressing so that the wearer could practice pressuring each toe individually. Note the battery pouch on the top strap of the participant's right foot has been integrated in the their sandal design.

In a workshop where we provided toy pianos and t-shirts one participant brought her own top and integrated the circuit layout in the design that was printed on the fabric [Fig. 8]. In another sound toy hacking workshop one participant embedded the sound circuits from two different greeting cards in a fur shawl [Fig. 8]. She stitched conductive threads into the shawl that acted as a directional stroke sensor. Depending on which way the shawl is stroked it triggers one of two different sounds.

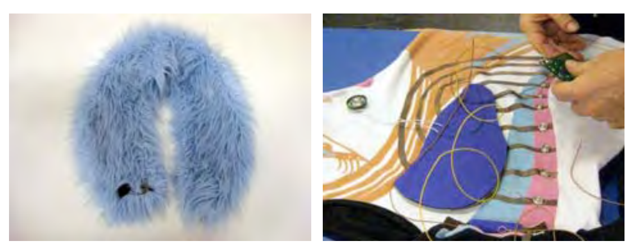

Figure 8) Participant projects: Fur shawl with integrated stroke sensors (left), personal Piano T-Shirt (right).

The example shown in Figure 9 on the left is a particularly beautiful versions of our tilt sensor in which the participant replaced the metal bead with a conductive pompom that she made from conductive fabric. The sensor was decoratively mounted on a handbag where it causes LED lights to twinkle as the handbag swings.

Figures 9) Participant projects: Conductive fabric pompom on purse (left), Knit glove stretch sensor (right).

The last example shows the knit stretch sensor fully integrated in the fingers of a glove [Fig. 9], which a participant knit overnight from one workshop day to the next. The bending of each individual finger triggers a different musical sound. The glove is part of a full body "one-man-band" suit that allows the wearer to trigger a whole range of instrument sounds though body movements.

Questionnaire Results

The aim of the questionnaire was to gather feedback regarding whether or not we are able to successfully convey our kit-of-no-parts approach to handcrafting technology in the workshops that we give. Were participants able to construct personally meaningful and valuable artifacts from the materials and tools we introduced? In turn, did the materials and tools we introduced make the technology more understandable? And were participants able to leverage an existing skill in order to learn something new?

The questionnaire was sent out to 104 participants who had previously participated in one of our workshops that had taken place over the last 3 years and lasted six hours or more. We received 30 replies of which 12 were male and 18 were female, ranging from 20 – 57 years of age.

How did the use of craft materials have an impact on the personalization of the resulting artifacts?

We asked participants what had become of the artifact they had created during the workshop and were pleasantly surprised that 12 participants reported active use of their artifact beyond the workshop context. This included having displayed their artifact publically, given it as a gift or using it as a demonstration to help explain E-textiles to others. Further 9 participants mentioned that they have it stored away as a memory of the workshop. Only one participant noted that they had cannibalized it for parts. Further 2 participants left the field blank. Practically all participants kept their final projects, making a strong statement for the permanence of crafted objects.

Did the craft material approach taken in the workshops make technology more understandable?

When asked what had happened since the workshop. 50% or more responded positive to having started another E-textiles project, feeling knowledgeable on and E-Textiles subject and staying in contact with other workshop participants. When asked what skills and knowledge learnt in the workshop were most useful and how these had had impacted their future practice the written replies were diverse, but one notable statement *"I feel like I can understand 'how'"* supports the conclusion that the workshop gave some participants enough insight to feel knowledgeable on the subject matter and capable of understanding technology as well as the affordances of craft practice.

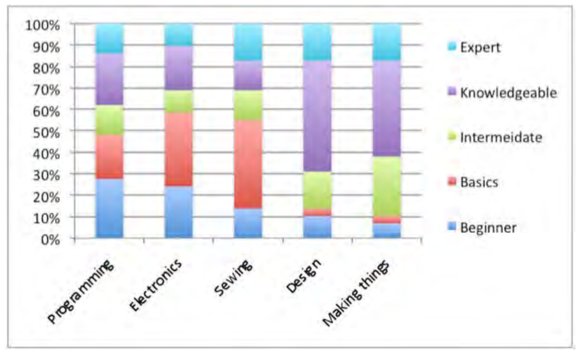

Figure 10) Graph showing how workshop participants rated their skills.

Were participants able to leverage an existing skill in order to engage in new activities?

The graph in Figure 10 displays how participants rated their skills from total beginner to expert in the areas of programming, electronics, sewing, design and making things. Participants rated themselves across the board with a tendency toward more *design* and *making things* skills. From the individual responses it is interesting to note that participants rated themselves *knowledgeable* or *expert* in at least one skill and total *beginner* or *basic skills* in another skill. This means that not only is the participant pool diverse in their skill-sets, but individuals come to the workshops feeling proficient in at least one skill and at an entry level in another. The downside of this is that not a single participant rated themselves to be below (nor above) *intermediate* in all skills and that the interdisciplinarity of the E-Textiles field possibly closes it off to complete novices.

While these results convey that participants come to the workshop considering themselves *knowledgeable* or *expert* in at least one domain, it does not answer the question whether they were able to leverage these existing skills in order to learn new ones. The following responses, displayed in Figure 11, try to answer this question. Two thirds of participants replied that they had helped another participant during the workshop and all but two participants replied yes to the direct question of whether they were able to apply an existing skill during the workshop. 80% or more replied yes to having challenged themselves, having engaged in new activities as well as having gotten excited about the new possibilities they encountered during the workshop. While these replies are not sure indicators, they at least support the idea that participants did not stick to their own domains and possibly having an existing skill set supported them in exploring a new domain.

How did participants experience the kit-of-no-parts approach taken in the workshops?

The following quotes were chosen to underline the influence that the kit-of-no-parts approach had on participant's experiences.

"Find unconventional solution for technical problems and simplify things. Hand's on working. Fast prototyping. Sharing knowledge among workshop participants."

"With e-textile/crafting work, the results are immediate and tangible. This shortens the design iteration cycle considerably and makes prototyping much more engaging than working with tools on a computer screen."

"I was surprised about the aesthetics and simplicity of solutions presented and found during the workshop. I was amazed about the seriousness and purposiveness the tutors and people in the DIY environment worked on the subject. I learned that excellence is not a question of resources and that it is important to share resources."

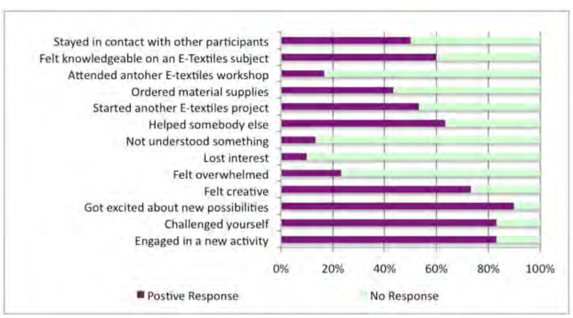

Figure 11) Graph showing replies that participants responded to with a positive response.

A KIT-OF-NO-PARTS

This section we evaluate how well our kit-of-no-parts approach, that we detailed in the introduction, is supported by our results as well as how it differentiates itself from building within a system of parts.

1) Personalize

When describing the results of the LilyPad Arduino workshops Buechley [5] makes the observation that the E-textile projects that people realize with the LilyPad toolkit look nothing like traditional technology. We would like to expand on this statement and say that the projects that people realize in our workshops are not only unique, unusual and diverse but they are also nothing like any commercially available interface. Handcrafting technology not only fosters the realization of personal artifacts, it also affords novel designs that represent the intimate relationships process of their making.

2) Understand Technology

The design of our textile sensors and other solutions documented in our online database are informed by a desire for them to be as legible as reproducible as possible. Technology constructed through craft techniques tends to be less hidden than technology that is machined. The scale and methods of craft production naturally afford visibility and in our designs we take extra care to showcase this affordance and not to hide functional elements beneath others. By examining our designs you should be able to draw information regarding their function directly from them. This is a conscious decision that we make because we believe that if technology is more apparent, then more people will be able to understand it and in turn craft their own examples.

3) Leverage Existing Skills

Situated in the interdisciplinary field of E-textiles our workshops attract a diverse audience. In any given workshop we have at least one electrical engineer and one sewing expert. This diversity has become a key aspect to how we are able to run our workshops, since participants are able to help each other, bringing their own knowledge into the workshop as a valuable resource for others.

In Pianos Not Stereos [6] Resnick et al. list two general principals for the kinds of "*doing*" that are most assistive to learning. To involve familiarity so that previous knowledge can be leveraged and for this to happen in a natural way. Without intention or planning we see these principals occurring naturally within our workshops where participants are faced with a multitude of challenges that include designing artifacts, constructing sensors, laying out circuits, programming microcontrollers and working with textiles. Participants will draw upon their existing skills and help others where they can. At the end of the day every participant has managed to navigate and work through the full set of challenges and as a result has built a unique artifact that is not only a result of personalization, but of the learning and making process that occurred.

CONCLUSIONS

We have described how craft materials support a more understandable approach to creating technology and that the results of this process can be more transparent and self-explanatory. The kinds of handcrafted interfaces created with this approach display creative use of materials to create personal designs that last. Participants in our workshops are able to conceive of and realize original interface designs from the palette of conductive fabrics and craft materials we provide. We believe that our approach to crafting technology, and electronics in particular, can be applied to build a richer and more diverse set of human-computer interfaces than established electronics design, prototyping and production processes allow for.

E-textiles as an interdisciplinary field offers great opportunities for engineers and craftspeople to leverage their skills, creating an environment in which both can learn from one another. By applying the kit-of-no-parts approach to other material and craft disciplines it should be possibly to achieve similar results.

ACKNOWLEDGEMENTS

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