Material improvisations with a new sensor material

Charlotte Nordmoen
c.nordmoen@qmul.ac.uk
Queen Mary Universiy London
London, United Kingdom

Andrew McPherson
a.mcpherson@qmul.ac.uk
Queen Mary Universiy London
London, United Kingdom

Figure 1: Example sensor objects made by designer-author Charlotte Nordmoen. A permanent magnet is typically mounted underneath or inside each object.

ABSTRACT

We present a selection of semi-functional prototypes developed from a new sensor material through a series of workshops and a longer-form exploration undertaken by four designers. We explore the challenges and opportunities of developing computational composite materials.

CCS CONCEPTS

• **Human-centered computing** → **Interaction design theory, concepts and paradigms**; *Empirical studies in interaction design*; • **Hardware** → *Emerging interfaces.*

KEYWORDS

Material exploration, sensor technology, computational composite, craft, embodiment

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1 INTRODUCTION

The increased interest in materials in the field of HCI has shown the importance of materiality in computation [8]. This has in part been driven by the move towards tangible interfaces and the Internet of things (IoT), as well as a desire to approach computation as a material such as making Bluetooth accessible to designers [9] and texture in data integration [1]. More often than not there is still a separation between the physical and the digital, where a material form gives shape to digital possibilities through sensors. These sensors are separate from the material form and often something attached on at the end.

We present an open-ended sensor material comprised of composites of conductive and non-conductive elements such as conductive threads and fabrics, copper tape, foam, rubber, plastic and yarn. The common element is magnetic induction: moving the conductive elements in a magnetic field results in a voltage which is amplified and subsequently sonified. Choices of materials or physical form were left deliberately open-ended in a series of design workshops and long-explorations. The resulting sensor objects represent semi-functional prototypes which occupy the space in between the tangible and the digital material.

In the context of this workshop our sensor material helps address material programming [10] as an embodied practice. We are interested in discussing the challenges and opportunities that arise from creating knowledge through material-led experimentation and the benefits of such a practice to the design development process.

2 MATERIALS

Sensor technology

In order to explore magnetic induction as a sensor material we need a system which can pick up human interaction, is lightweight, responsive, gives some form of feedback and is easy to test prototypes with. We designed a purpose-made preamplifier board for use with the Bela embedded audio platform [4] as outlined below. The prototyping setup is shown in the companion materials.

Our sensor material consists of three types of materials: magnetic, conductive and non-conductive. The signal is strictly speaking only governed by the relative motion of magnet and conductive element, while the surrounding non-conductive material functions as a medium to guide and constrain the qualities of movement that are possible, and the way those qualities are presented to the user. For example, differing levels of compressibility or flexibility will give rise to different patterns of motion. Nonetheless, there are certain global properties that are intrinsic to every instantiation, including its frequency response, which approaches but does not reach DC, and its particular balance between large movements and fast movements.

Sonification of the signal takes a deliberately simple form of modulating the amplitude of a sine tone, but owing to the characteristics of the sensor this approach nonetheless provides rich and nuanced feedback, making immaterial magnetic induction 'tangible' and allowing us to gain a tacit understanding of the sensor material. The sonification had the added benefit of freeing the eyes to focus on making and testing the objects during the development rather than having to look at a screen. It also enabled us to make semi-functional prototypes where the sound acted as a stand in for an imagined outcome of the interaction.

Material exploration

Craft practice proved a fruitful way of exploring the possibilities of this new sensor material. Craft practitioners work with "material quality" – what woodworker and professor David Pye described as the subjective interpretation of what a material can be. [7]. This is different from the objective and quantifiable characteristics of a material. As an example of material quality, Pye described how British walnut wood is beautiful only because of the skilled work put in to make it so.

3 DESIGN DEVELOPMENT

The sensor material was explored in a three-stage process. We began with a personal exploration focussing on the tactile and interactive possibilities of the sensor material, taking Karana et al.'s material-driven design methodology [3] as a starting point. This was followed by two workshops with 12 designers in total. During the workshop the designers learned to make sensor objects and developed their own understanding of the sensor material through exploration.

Finally, a longer-form exploration with four of the participants from the workshops opened up a deeper understanding of the sensor material, as well as a different working environment and material selection.

In the longer-form exploration, each participant was given a kit, a design brief and a sketchbook to take home. The kit consisted of a microcontroller optimised for easy testing of the sensor objects, as well as various magnets and conductive materials to get the designers started with the exploration. Independent material sourcing was encouraged. An open brief to design smart home devices was given as a way of focusing the exploration with the expected outcome of a semi-functional prototype, in the sense that it created a signal that could be heard through sonification. However, the designers did not have to think about how that signal was processed further once the signal was inside the computer.

The Finnish architect Juhani Pallasmaa has written extensively on the importance of touch in architecture [5] and by extension the home, yet much of smart home technology has the feel of computers, touch screens, etc. We believed our particular sensor technology might offer an interesting, alternative approach to designing for the smart home.

4 REFLECTIONS

Personal exploration

In my [CN's] personal explorations I set out trying to frame the sensor material using the material driven design methodology [3]. The initial steps consist of "tinkering" with the material in order to understand the possibilities and constraints of the material. This turned out to be a challenge considering the material I was working with was a composite of three different material categories and each of those material categories could have any number of characteristics. Additionally, the way these three material classes were combined would result in widely different interaction, experience, signal.

I found that the field lines of the magnet made a difference and that the conductive material should move across the change of poles for a strong and reliable signal. The way the circuit was formed of the conducting material also made a difference. Thin lines of conductive material were more effective than big areas of conductive material. After experimenting with the material for nearly two months I was no closer to give a clear explanation of how the sensor worked. I could create reliable sensors but I wouldn't be able to explain exactly how they work. Examples of the various objects made during this period is shown Figure 1.

Ambiguity

The ambiguity of how the sensor worked was expressed by several of the participants in the workshops. Five participants in the first workshop had made objects they identified as similar in that the interaction relied on some form of the deformation of the sensor object. Yet when they came to explain what their objects did, they all had a different explanation of what their object was and what it sensed. The two most extreme cases were a stack of foam with a copper wire randomly stitched through the layers, which are interacted with by "hitting". The participant suggested it might sense how angry you were if used in a punching bag. Another participant made an object from wadding and conductive tape. The participant described it as a stress ball that you can pat and it will send a message to a friend to let them know you are in need of their support. This diversity of interpretations suggests that ambiguity found in the sensor material act as a resource for design [2].

Not all of the sensors that were made during the workshop worked. Some were abandoned because they were thought to be too complex. Others were abandoned because of technical difficulties where the circuit was not closed. There were also a rare few cases where the designer tried to force their concept onto the material and the material did not yield.

Material Experience

Several of the workshop participants felt the sensor material allowed them to focus on the experiential qualities of the objects they where making. In some cases this was prompted by exploring the relationship between sound and 'material connotations' whereas in the longer study the experiential properties was explored in a conceptual way.

The prototypes from the longer-form exploration were motivated by a similar interest in the experiential qualities of the sensor material. One participant, for example, had made a series of sketches of her design ideas concerning fur-like sensor objects. One of these objects was a furry lamp where you could touch it to change its colour; however, the purpose was not to change the colour, rather to "give you the feeling that you could touch the light."

Developing an understanding

Moving from the workshops to the longer study, for participants that took part where inspired experiments undertaken during the workshop fed into the longer form exploration. Either as particularly good material combinations, creative concepts and new technological knowledge. One of the participants noted how in the workshop she was led by material exploration. She was interested in the particular properties of rubber and how that material shaped the interaction with the object she made. However, in the longer form exploration she focused on idea generation around how and what this sensor material could be used for in the home. She described her processes turned on its head when working towards the brief.

Diversity in outcomes

The four outcomes of the longer exploration were all very different. One was an interactive dining experience where the plates and the cutlery were augmented by the sensor. Another was a wearable that would alert you to bad posture, the third explored how books could be interactive mediated through this tactile technology. The last was a series of concept sketches of tactile and meditative home technology such as light and tactile furnishing as well as robot pets. Examples of these outcomes are shown in Figure 2.

To call some of these objects "prototypes" is a stretch, as several of them remain as material samples. However, they speak to the beginning of four interesting design projects.

5 DISCUSSION

Co creating objects and material understanding

Through the process of making objects the participants developed an understanding of the material alongside their design development. This methodology of developing new sensor materials through improvisation and experimentation is more akin to Vallgårda's Bricolage practice [11] where insitu explorations rather than the more goal directed approach to making sensors taken by Perner-Wilson et al. [6].

Turning to the materials

On the other hand Perner-Wilson et al.'s methodology of craft practice is also central to our work. Our sensor material is a computational composite [12] yet it enables a craft-based working process rather than the need for specialist, technical tools. It favours working with the materials at hand, letting the designers discover for themselves what 'qualities' in the material they wish to bring to the fore. The physical manipulation of conductive and non-conductive materials chosen by the designer change the response and interactivity of the composite, and without directly editing the code.

One clear opportunity is the fact that there is no coding skill needed to develop these materials. And relatively simple knowledge of electronics in the sense that you need to know about circuits (e.g. how to close the circuit and not short-circuit). This enables a broader range of designers to work on design of interactive systems with skills that differ from traditional HCI design.

Figure 2: Selection of outcomes from the longer exploration. From top left: Wearable necklace to help with bad posture; stitched pocket exploration for interactive books; fur proof of concept; iteration of posture helping wearable, imagined as a tight fitting garment for the upper body; interactive dining prototype

Questions we want to address

We propose to discuss research through design for developing new composite materials. What are the best methodologies for this process? How do we evaluate our results? We will bring a selection of semi-functional prototypes from our material exploration. In our case we used sound as a way for the designers to experience the signal in a tangible way. Some of the designers never moved away from the idea of sound being the final outcome. Would the outcomes have been different if the feedback was something other than sound?

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