Wearable Rhythms: Materials in Play

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Abstract. This paper will consider a future of wearable fluidic materials through a frame of embodied making and imagination. It will be presented through the design, construction, and reflection of a design case study: 'Wearable Rhythms.' This exploration is undertaken by drawing upon the rhythm of natural, elemental materials such as water and air. The aim of the study is to develop material-led design thinking to support soft, haptic, palpable, affective, tactual and computational experimentation. We conclude by considering how the experiment can provide new capabilities, both embodied and speculative, for design researchers to explore the invention of emerging technologies for Wearables.

Keywords: Rhythm · Play · Elemental · Material imagination · Soft robotics · Human-material interaction · Speculative design · Temporal · Currents · Ephemeral

1 Introduction

1.1 Background

The fast-emerging soft robotics movement is shaping a whole set of meta-materials, which are ripe for development in exploring the affective, aesthetic, imaginative and critical dimensions of wearable technology. These morphable machines are uniquely appropriate to the pliable and adaptable nature of textiles; appearing as a soft skin ready to interface with the human body.

Lewis Lab [1] and Whitesides Research Group Whitesides [2] (both at Harvard University), MIT's Soft Active Materials Lab [3], Bristol SoftLab (BRL) [4], AMOLF, Amsterdam [5] and the Faboratory at Purdue, University, Indiana [6] are formulating sensor-triggered artificial muscles, shape-changing fabrics, self-healing materials, and micro-fluidic systems. However, having gained traction across the field of HCI, [7] these developments stay underexplored for the creative, material and practice-led disciplines of fashion, textiles, and jewelry. Thus, fresh opportunities are evolving for material designers to propose alternative approaches and scenarios beyond the classical wearable application of soft exoskeletons. [8] Second Skin, [9] an emergent bio-system for the body is one such example; it is crafted as a synthetic bio-textile, actuated by sweat, and driven by living bacteria. While not a commercially available product, the prototype invites us to reconsider a creation, or even production process, whereby actuators are positioned as 'grown rather than manufactured' [9].

A. Marcus and W. Wang (Eds.): DUXU 2017, Part II, LNCS 10289, pp. 737–746, 2017.
DOI: 10.1007/978-3-319-58637-3_56

This paper, therefore, extends and builds on our previous methodology of an embodied approach [10] to the design of a 'soft machine' - but seen through the lens of speculative design. Shaped through the developing 'material turn' in HCI, [11] this paper will discuss how an embodied engagement with these materials offers the possibility to re-imagine the experiential characteristics of dynamic matter [12].

2 Related Work

2.1 Bodily Dreamscape

Through a bodily 'dreamscape,' we can now consider the relationship between reflective, [13] embodied [10] and tacit [14] knowledge with the conceptual, fictional and speculative.

Previously, we have used an embodied relationship with material to build an inter-active composite textile using tacit textiles knowledge; exploring a visceral engagement with material through a series of small-scale experiments using fluidic and pneumatic actuators to develop expressive textile surfaces [15].

Within HCI literature, scholars place emphasis on the value of an embodied approach to developing novel forms of interaction. Klemmer et al. [16] advocate 'thinking through prototyping' as a more nuanced method of developing the digital-physical blur in tangible computing. Similarly, Wilde et al. advocate the importance of our 'sensory motor skills.' [17] Meanwhile, fashion and textiles theorist Pajaczkowska reflects on our tactile relationship with the imagination; [18] whereby the act of physical making can activate subliminal tendencies, in which, 'neural pathways of kinaesthetic memory serve as pathways for unconscious thought, fantasy and meaning' [18].

Speculative Design can be thought of as adding a complementary dimension to an embodiment approach. Wakkary et al. introduce the term 'Material Speculation' whereby 'Material speculation utilizes physical design artifacts to generate possibilities to reason upon' [19].

In this paper, the design process of 'Wearable Rhythms' is presented to articulate a subjective and reflexive approach towards the process of emerging technology-development. The prototypes are composed of programmable pneumatic and hydraulic channels. It is proposed that through devising this on-body system, a design space is offered for the practitioner to imagine fluidic interaction through a material system – reflecting on flows, blurs, and rhythms.

2.2 Temporal Expressions

Soft programmable materials possess the ability to reframe textiles from a position of static expressions to one of temporal expressions. As these materials grow from stationary to dynamic soft systems, designers translate concepts from the disciplines of animation, music, dance, theatre, and film, into a new context of computational materials. [20] Worbin, for example, argues for textiles to connect with the 'time arts.' [21] This is closely connected with Berzowska's analogy of 'stage production' [22] and Robles and Wiberg's emergent vocabulary for novel interaction approaches, such as 'elements scale, datum, rhythm, transformation, circulation, approach and entrance' [11].

Winkler et al. present ‘MetaSolid,’ an ‘imaginary material’ built on the concept of programmable phase-change properties. Oscillating at whim between hard and soft, the concept of MetaSolid suggests fresh user interactions with material such as ‘crumbling’ or ‘tickling’ as opposed to purely conventional interactions such as ‘folding’. [23] Using a similar example, Rozendaal et al. question how, in the context of domestic products, human interaction could shift for shape-changing materials.

Passive materials are archetypically triggered active through human agency. Kinetic interaction qualities offer a life-like character to passive materials. As these products become actants, our relationship to the product is altered. Rozendaal et al. thus asks us how we might consider, ‘*collaborating* with these products, as opposed to *using* them.’ [24].

Building on the exploration of future flexible interfaces, the design process, and experiments in this paper aim to transform air and water into a form of wearable programmable matter. Can we imagine affective terms to express sensorial and affective material interactions such as seeping, oozing, soaking - The Crying Dress?

These descriptions can offer an enhanced mode of reflecting on and about a wearable interface, thus evoking new experiences, feelings, and interactions. Arguing that rather than compartmentalizing and engineering a wearable experience through pre-scripted procedures, we align with Sengers et al. in using physical computing to design for ‘open-ended engagement’ [25].

Consequently, how can embodied making inspire new speculative materialities? If reflecting with and through materials, as posed by Schön, [26] and Sennett, [27] can stimulate a distinctive type of thinking, this paper questions what type of bodily experiences and material interactions are open for discovery? How can a fluidic materiality extend the capacity of HCI? Here we take Merleau Ponty’s theories on embodiment [25] as viewed through Bachelard’s phenomenological approach whereby ‘imagination’ flourishes in matter [28] and the tools of the designer transform into extensions of imagination.

2.3 Elemental Materials

Drawing insight from elemental matter, we can acknowledge that our experience of the natural elements such as rain, sun, wind and fog is sensual and multisensory. Bachelard conveys the unconscious attraction to water as being due to its ‘viscosity’ and organic associations [29].

Designers have experimented with these natural materials through performance landscapes. Theatre-designer, Shearing’s ‘The Weather Machine’ [30] devises an immersive environment embedded with light-breezes and sprinkling rain, aiming to create ‘gentle, reflective immersive spaces.’ [30] While, architects Diller Scofidio + Renfro’s Blur Building is formed in its entirety out of mist, as a pure water vapour construction, the architects identify this transient set-up as an atmosphere rather than a building. [31] It is these specific atmospheric qualities which have the potential to evoke sensory and emotional engagement.

Organic materials have been employed within HCI interfaces to offer novel and sensory forms of interaction. Rudomin et al. expand on this notion of incorporating water and air as an interface, with an interactive art installation, ‘Fluids’ - asserting that this type of 'tactile reference expands the imagination of the user.' [32] Further, Döring et al. introduce their design space of the Ephemeral User Interface (EUI) which captures fleeting moments, for example, soap bubbles as an interaction element. The inherent materiality of translating transient phenomena found in nature such as ice, bubbles, water, fog and air into a user interface is presented as offering playful interaction qualities [33].

3 Wearable Rhythms

3.1 Tactile Experiments

To translate fluid and invisible phenomena such as water, air, and sound into a visible, tactile wearable; early material experiments were devised built on soft robotic structures. These soft elastomer channels and chambers (Pneu-Nets) [34] actuate in response to air pressure. The molds are fabricated through a 3D printer, and then soft silicon (EcoFlex 30) is poured into the cast. Air is pumped through the chambers, directing the soft bodies to bend and twist. This air can be further controlled and programmed through a microcontroller and sensors.

The designed elastomer structures were embedded with various color and texture variations. The internal pattern of the chambers then creep and squirm along giving the suggestion of anthropomorphism. This led us to imagine a wearable prototype with crawling textures. From this it can be proposed that a material surface can seem to be crawling, creeping, sliding, slithering or even wriggling (Fig. 1).

3.2 Prototype: Water Dress

The Water Dress Wearable is based on a similar principle of the soft elastomer channels and chambers from our tactile experiments. This time, however, we have fabricated interconnected macro-fluidic channels, which are programmable and interact with the environment by sensing sound frequency.

Developing soft-material based fluidics enables a shift away from the traditional focus of microfluidics as purely a medical diagnostic application. 'Unconventional' micro-fluidics, as defined by Nawaz et al. [35] locate microfluidics into new contexts such as robotics and electronics and assert that expanding this discipline will inspire creative approaches. The following case-study reflects on the development of our experiment.

Design Development

Microfluidics are traditionally fabricated in rigid materials. A soft fluidic layer was tested not only for potential tactile and wearable properties but also perceptual values; soft materials, as opposed to hard materials, own, according to Karana et al., a quality of 'being *alive*' [12].

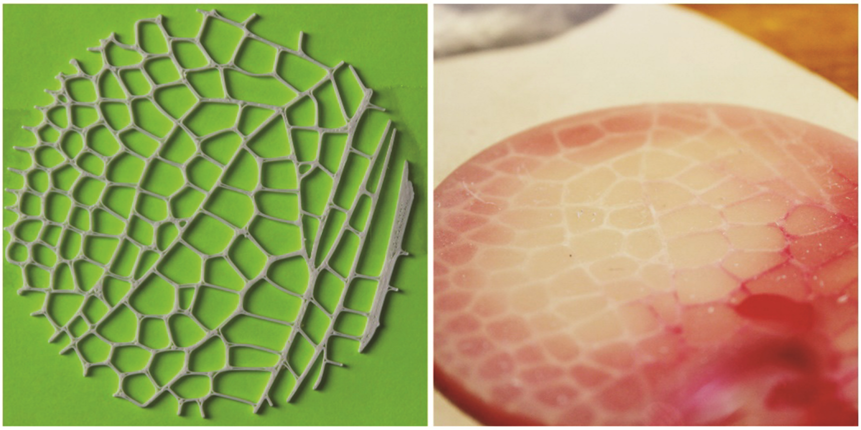

Fig. 2. Initial tests on silicon microfluidic sample. Left: 3D printed ABS channels. Right: red dye liquid flushed through dissolved channels in silicon material. (Color figure online)

Fig. 1. Soft robot design process. Tactile rhythm is discovered through pneumatic actuation.

The following design process is extracted from the analysis of personal experience, using a first-person methodology. Based on a fabrication approach towards microfluidics introduced by Saggiomo and Velders, [36] the microfluidic is fabricated by 3D printing Acrylonitrile butadiene styrene [ABS] channels as a scaffold. Encapsulating the channels within a single layer Polydimethylsiloxane silicone (PDMS) and subsequently dissolving the ABS scaffolds in acetone to reveal hollow channels. This method offered scope for creative development as no specialist laboratory facilities are required. It is also adaptable and quick to fabricate. In the following experiment, EcoFlex silicon replaced PDMS to offer extra elasticity. 3D printing and laser cutting methods were used to fabricate the ABS scaffold (Fig. 2).

For the wearable prototype experiment, we employed water imbued with blue dye; the liquid medium was pumped throughout the dress filling the channels and chambers (Fig. 3).

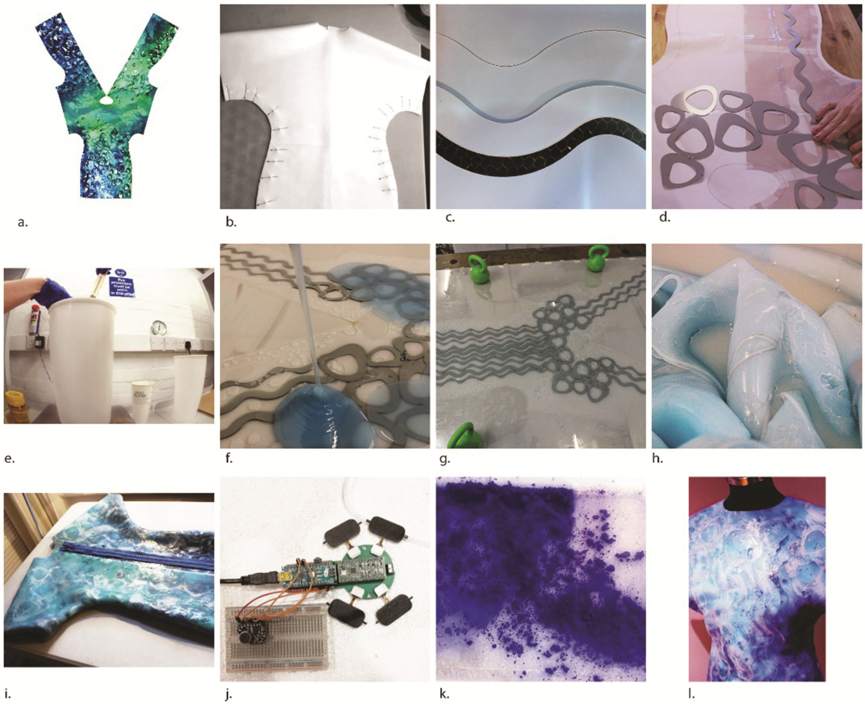

Fig. 3. Making process of the water dress. (a) digital print. (b) toile (c) laser cut ABS (d) constructing ABS pattern (e) silicon mixture (f) casting the mould. (g) cure for four hours. (h) Soak in acetone. (i) final construction of dress. (j) electronics prototyping. (k) blue dye solution. (l) flushing coloured liquid through the dress.

We see this approach as a method to enhance expressivity, colors can be interchanged, and various states of opacity and iridescence can be achieved. By blending these pigments together, the designer can adopt the role of the painter, alchemist or cook rather than the programmer or engineer.

Technical Development

To assemble the macro-fluidic material, channels were laser-cut in ABS and hand-constructed together. The dress was cast in a laser-cut mold with a soft polymer (Eco-flex 00-50), and the ABS channels were dissolved in acetone. The prototype hardware is driven by a micro controller (Arduino Nano) and four controlled micro-pumps and a pump driver (mp6-QuadKEY Bartels). [37] Liquids are pumped through the macro-fluidics using 1.3 mm Tygon tubing (Fig. 3).

Sound is detected via a microphone, specifically a sound frequency sensor detecting bass, mid range, and treble levels. We used the 'audio-shades' development board by MaceTech [38] which is built on the MSGEQ7 chip and an amplified micro-phone. The MSGEQ7 chip splits the signal into seven frequency bands; 63 Hz, 160 Hz, 400 Hz, 1 kHz, 2.5 kHz, 6.25 kHz, and 16 kHz. These bands offer a direct current representation of the amplitude of each band. [39] The bass sounds are low frequency (63–140 Hz), and the higher trebles are (1 kHz–6.25 Hz). Software to power the development board was sourced and adapted from the Rheingold Heavy online tutorial [40] (Fig. 3).

The Water Dress is programmed to detect high-pitched frequencies which subsequently trigger the pigmented ink to flush through the macro-fluidic wearable.

The making of the prototype began to address another notable set of questions. Can we conceive a space of design-led scenarios for technology development? (Fig. 4) Using the concept of wearable macro-fluidics, new types of material interaction start to emerge. Stimuli-responsive hydrogels, [41] for example, have the potential to be embedded into channels, resulting in shape-shifting adaptive surfaces and rendering the garment tunable in shape. Hybrid recipes could extend to other types of pigments experiments such as nano flakes for iridescence, UV sensitive photochromic pigment for chromatic change, or hydrophobic sand for texture transformations.

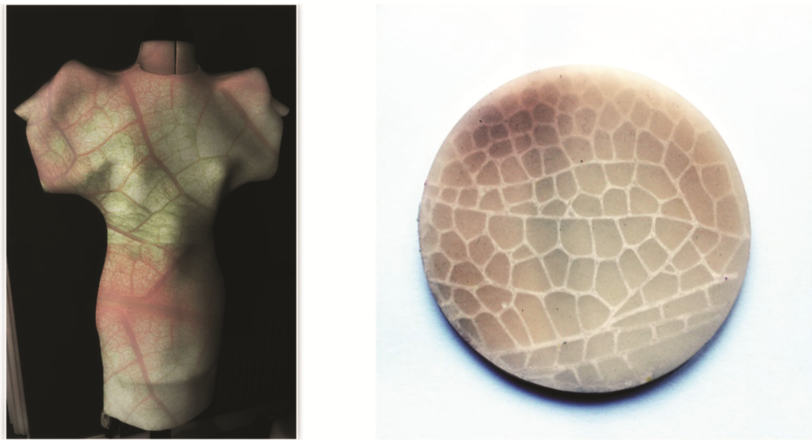

Fig. 4. Left: speculative macro-fluidic dress with pigmented crimson veins. Right: microfluidic vein pattern sample.

4 Future

In the next phase of this project, we wish to develop a soft programmable material platform, using a multi-material 3D printer to fabricate soft material fluidic systems, testing novel material concoctions, which can be programmed inside the elastomer chambers.

A framework to evaluate on the speculative and rich possibilities of Wearable Fluidics will be employed. In devising the evaluation structure, we draw on Döring et al. proposed areas for future research, namely 'Ephemeral Smart Materials' [33]. Using a sensory ethnography approach [42] a workshop of material-led design participants will engage in their own, embodied design of a wearable fluidic system, testing out a set range of programmable elemental materials. Participants within this framework might focus on as Döring et al. states, 'the design and invention of a new material instead of selecting an existing one.' [33] In this fashion, the fabrication and speculative development of novel wearable interfaces, interactions and materials recipes are led through design and user-experience rather than focusing on purely technical constraints.

5 Conclusion

In this paper, we have discussed the opportunities for wearable and imaginative material alchemy. We have presented Wearable Rhythms, a design experiment which has explored the potential use of elemental materials such as water and air to open up design opportunities for Wearables as expressive interactions. To conclude, within an R&D model of soft materials, there are benefits to an embodied and speculative approach. The material designer can be equipped and re-wired with an expanding material imagination 'tool-box.' Rather than calling themselves 'Digital Hackers,' such designers could rebrand themselves as 'Material Hackers.'

Acknowledgments. The author would like to thank Laurence Symonds for support with electronics prototyping and coding.

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