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## A Space-time of Ubiquity and Embeddedness

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# Computational materials: Embedding Computation into the Everyday

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## ABSTRACT

This paper presents research into material design merging the structural logics of surface tectonics with computation. The research asks how the understanding and design of interactive systems changes as computation becomes an integrated part of our material surroundings. Rather than thinking the ubiquitous system as something that is embedded into the existing context of the built environment, this paper speculates on the design of bespoke materials specified and designed in respect to both their structural as well as their computational performance. The paper asks: what are the design practices that allow us to think of material as extending both in space (structure) and over time (actuation)? How can we imagine our surrounding environment as actively sensing and responding to our presences? How would it be to inhabit a live space?

## General Terms

Design, Experimentation, Human Factors.

## Keywords

Architecture, ubiquitous computing, material practice, interaction design, material specification and integration.

## 1. INTRODUCTION: DESIGNING PERFORMATIVE MATERIALS

*"What is worth noting is that nothing allows us to presuppose a greater dissipation of the elements of which the dream is constituted. I am sorry to have to speak about it according to a formula which in principle excludes the dream. When will we have sleeping logicians, sleeping philosophers? I would like to sleep, in order to surrender myself to the dreamers, the way I surrender myself to those who read me with eyes wide open; in order to stop imposing, in this realm, the conscious rhythm of my thought."*

*Andre Breton Manifesto of Surrealism, 1924*

The field of operation for the design inquiry which this paper presents is situated in constant reciprocity between architectural materiality and performance and a speculative investigation into the architectural site of the bed. Architectural design is entering a radical rethinking of its material practice. Advancements in

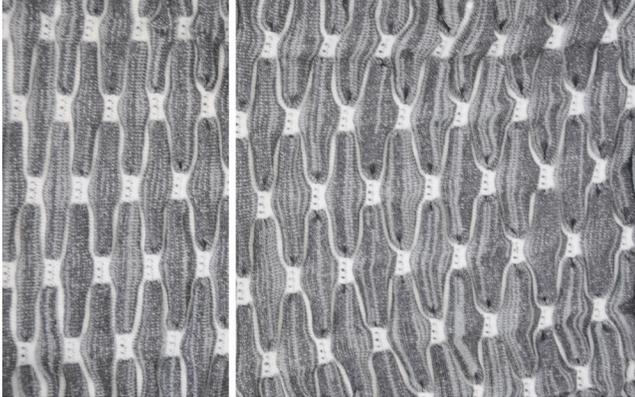
material science are fundamentally changing the way we conceive and design the materials by which architecture is made. Where industrialisation brought about an era focused on standardisation and mass production, the contemporary information age is instigating a new material practice where materials are highly engineered and customised for their particular purpose. In this practice the design of artefacts is also the design of materials. From nylon stockings to the petrol we drive our cars by, we are surrounded by, man made materials designed in response to sets of highly specified performance requirements.



Figure 1. The bed surface

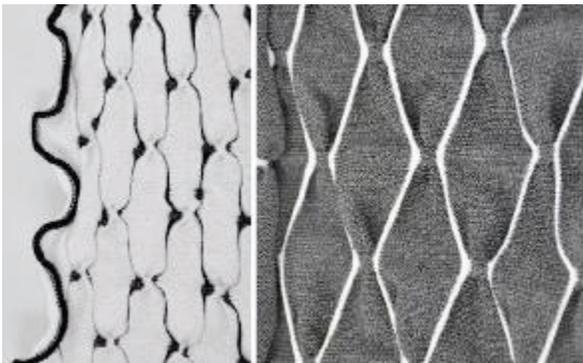
This development presents a shift in the way that we think about embeddedness. In architecture the idea of ubiquitous computing has become synonymous with a sensor based switching of the existing infrastructures for lighting, heating or air conditioning. Under these conditions, the structures of sensing and actuation are held apart from the spatial intent as well as the structural performance of the building membrane. As architecture is introduced to ever smarter materials that are conductive, can phase shift or otherwise include computationally steered events, this new material practice allows the thinking of new intersections

between the computational and the material. This leads us to consider the spatial and the temporal as interdependent dimensions. As suggested by Michelle Addington architecture is presented with a shift from a formal culture focussed on spatial extension, to a new focus on material behaviour: “[w]hereas standard building materials are static in that they are intended to withstand building forces, smart materials are dynamic in that they behave in response to energy fields. This is an important difference as our normal means of representation in architectural design (through orthographic projection) privileges the static material... With a smart material, we should be clearly focussing on what we want it to do, not how we want it to look” [1].



**Figure 2. Experimenting gradient patterns developing the material specification**

Addington presents the departure from a formalist and fundamentally autonomous understanding of architectural production to one that is linked intrinsically to the material, the performing and the present. If architectural culture is predominantly situated within the abstracted place of representation, configuring its drawings in respect to a model of notation and interpretation, this new focus posits material as something always actively in a process of performance. The idea of the actuated material, the phase changing and the smart is therefore not different in kind to seeing the structural as performing and active. This new similarity allows for rethinking their integration and exchanges.



**Figure 3. Integrating Lycra® in pattern for contraction control**

## 2. TEXTILES AS A MEANS OF MATERIAL SPECIFICATION

The research presented here investigates textile structures as a means of material specification. Textiles are integral to the architectural tradition of construction. As both structure and lining, textiles are ubiquitous in the making and inhabitation of architectural space. Already in the 19th century, the architect and art historian Gottfried Semper referred to textiles as one of four core crafts that are the origin to architectural making. In Semper’s thinking the textile wall holds a singular position as “...the true and legitimate representations for the spatial idea” [2]. In his unfinished influential collection *“Style in the Technical and Tectonic Arts; or, Practical Aesthetics”* of 1870 [3], he devoted his first book to an elaborated study of the different textile techniques, one of four technical categories he developed altogether: textile, ceramics, carpentry and masonry. Although occasionally interpreted as merely a technical, formalist study, Semper’s intension was to articulate the four technical arts in *Style* as a guideline for the modern architect, looking at more simple forms of art to which architecture can discern its formal laws [4].



**Figure 3. Integrating conductive yarns for sensing.**

Semper identified that motives are technical in origin, but transformable in material, and symbolic in application. Eventually, his investigation was meant to trace the development of art forms as a manifestation of a more extensive cultural idea that is influences both intrinsically, by employing materials and technique to a specific purpose, and externally, by the influence of personal, social and cultural conditions. Rebecca Houze, specifically relating to Semper’s use of the term *Bekleidungsprinzip* relating to a building’s “dressing” (commonly translated as “cladding”), proposes that textile is a structuring principle that lends itself well to a new methodological approach in early modernism [5]. It is only through Semper’s followers, she claims, that we begin to see the reference to cloth in building, not just as a theoretical concept, but a visual, material language of form. Her assertion that textile, as a medium, has a transformative power that becomes a catalyst for art and design, is as relevant to our research as it was for the architects and designers of early modernism. The textile structures of this investigation are seen as a form of architectural practice within academia, and serve as both actual material probes as well as “structural-symbolic” probes, in Semperian terms, if viewed as models to scale. In this case, the computational knitted models serve as metaphorical images of a much larger architectural artefact.

Our central interest in textiles in an architectural context lies with their structural potential as a particular class of composite materials. A composite material is a combination of at least two materials that are integrated to form a new material composition

with enhanced performative attributes that surpass the individual performance of each material on its own. Textile-based composite materials are normally made up of reinforcing materials that are fiber-based imbedded into matrix materials or resins. In this research, textiles are looked upon as strategies for making composite materials. Weaving, knitting, lacing or crocheting are structures that allow the composition of fibres. Textile design is a material practice led by a deep understanding of material performance and construction, collapsing an interest in pattern, decoration and structure as one performative ideal.

Our research concentrates on the design of highly specified membranes that incorporate computational as well as structural performances. Our work explores the collapse of sensing, actuation and structure into one integrated membrane. Learning from advances in the technical textiles industry, we are using high performance structural fibres such as carbon fibre, glass fibre, aramides and extruded polyethylene monofilament with conductive carbon loaded fibres to investigate the meaning by which the textile membrane can become a conductive stratum for robotic sensing. Our research is predicated on a series of design investigations that build new interfaces between architectural design tools and CAD CAM knitting machines. These parametric CAD tools, which are capable of controlling complex geometries on varying tectonic levels, allow us to explore how to integrate material design with architectural thinking, thereby enabling the consideration of behaviour of the overall surface as well as the local stitch, during various phases of the design process.



Figure 4. Experimenting with coatings for air tightness.

Knitting is particular, even in comparison to other textile technologies such as weaving, braiding and non-woven technologies, enables flexibility of design. Historically, it is one of the more recent methods of textile making; with the oldest surviving examples of knitted fragments dating from 200 AD found in Syria, and recognizable as socks. These serve as a perfect example to the flexible and elastic nature of knitting in particular, which makes it inherently suitable for solutions of complex geometry such as the heel. The elasticity of a particular piece is determined by the inner structure of the knitted surface, the technique of creating interconnected stitches out of a continuous thread, together with the specific material properties of that thread or yarn. Consequently, knitted surfaces exemplify the distinctive interconnectedness between form and material. Our proposal is based on using the technology of industrial flat bed mechanical knitting machines, enabling the rapid production of none repetitive structures as well as a complete change of material at almost any given stage. In this way, we can devise performance specifications driven by spatial intent and resolved through direct material manipulation. Using parametric tools, that are computationally steered, we are finding ways of producing

differentiating patterns that shift in their performance. Here computer coding becomes a way of “writing form” so as to specify the material in respect to its differing yarns and structures. Stretching and contracting, soft and rigid and conductive or non-conductive, these patterns are driven in respect to the programme of intents. The research explores the potential of interactive three-dimensional knitted surfaces bearing different strategies for the definition of three-dimensionality in their geometry and pattern. Pattern, traditionally in textile design means both the dressmaking pattern that is the general shape or figure of the surface boundary, as well as the pattern of the knitted rows and characteristics of the stitches, which form the distribution of geometric components over the knitted surface. When using a double bed flat knitting machine, the characteristics and parameters of the knitted surface are predefined, and the fabrication is rapid and accurate. This is in contrast to the prevailing, somewhat wasteful, architectural material practice, which concentrates on cutting sheet materials to shape, and bending them to form.

### 3. LISTENER: IMAGINING AN ACTIVE SPACE

How can this imagination of a structure sited in middle of the activity of its computational and structural performance become meaningful to its inhabitants? How can we make the integration of behaviour and form meaningful within the lived space of our surroundings? In the design investigation *Listener* we are exploring how programme, spatial intent and behavioural design intersect. *Listener* is a bedspread that ‘listens’ to the bedside murmurings of its sleepers. Sited within the intimate space of sleeping, *Listener*, occupies a place where the idea of use and conscious action are negated. In sleep, there is seemingly no function to optimise or experience to augment. Sleeping, and specifically the process of falling asleep, involves a state loosening of cognition and perception, where the idea of ubiquitous interaction becomes that of co-existence.

*Listener* explores the idea of a textile membrane that has an inherent capacity to sense and react to its surrounding. Collapsing the idea of the controlled and the controlling, *Listener* is the making of a material that has its own, autonomous, relationship to its environment. The textile is treated as a *composite material* that through its inherent conductivity allows for the passing of computational signals, but also through its exceptional structural strength, and through its treatment, gains new properties.

As such *Listener* is a composite fabric with its own nocturnal rhythms, recurring in response to the cyclical intervals of sleep and awakening. The fabric is coated with a polymer coating making it able to hold air. The polymer is designed with small scale hole patterns within the coated surface allowing the air to escape over time, creating a rhythm of inflation and deflation; a continuous pulsing of presence. As an actuated surface *Listener* senses the space around it and responds to it through a shifting of its breathing pulse. The material is active both as structural membrane as well as sensing strata. Composed with integrated conductive fibres knitted directly into the material and thereby becoming part of the material specification, *Listener* embeds touch sensors that allow the material to sense its own conductivity. In a very straight forward sense this is done by integrating soft switches [6] in to the material construction. These open pins ‘listen’ to the closing of circuitry mapping conductivity to the instigation of action.



**Figure 5. Experimenting with air inflation**

The material thereby becomes *sensitive* as it registers changes in the conductive flow through the material. As the material moves, or as users touch and interact with the material, they actuate the sensor, which in turn informs a microprocessor that ultimately switches on and off an air blowing device. This self-sensing, the continual tracking of conductive flow through the material is the basis for the programming of *Listener*. The movements of the surface are registered and in turn passed on to instigate new movements. The circularity of this feedback loop creates a continual process of self-production, of self-sensing and self-response.

The material design is developed to further define this circularity. Being a knitted surface with differing levels of density, differentiating the connectivity and therefore the inherent sensitivity of the material, In this way the material itself incorporates the potential for generating ‘noise’ in the signal. Moving deliberately away from an ideal of isomorphic information passing, towards the distorted and the misinterpreted, it is our aim to emphasise the material presence of the system and to allow an internal shifting of the movement patterns that make up *Listener*'s behaviours. In the same way as in the Chinese whispering game, where children whisper sentences or phrases down the line from one person to another, the changing meaning of the words are the source of playfulness and register the mutations of message as it travels between the players.

The interactivity of *Listener* is therefore linked to the material of *Listener*. As such *Listener* proposes that it is exactly the intersection between the material and the computational that relates the meaning of interactivity. Much like the information passed to the microcontrollers, the information passed through the system is minimal, yet in its overall affect has the powerful ability to change the rhythmic structures, and therefore the temporal extension of the project. This acknowledgment of the complexity of the interrelation between information technology, material and human life corresponds to Katherine Hayles' assertion in *How We Became Posthuman* that: "In fact, a defining characteristic of the present cultural moment is the belief that information can circulate unchanged among different material substrates. It is not for nothing that "Beam me up Scotty," has become a cultural icon for the global information society" [7]. *Listener* exemplifies the idea of the feedback loop between the subject and the environment, between organic and electronic components, but rather than endorsing the idea of the disembodiment of information, body and material play a significant role.

#### **4. REFERENCING THE BEDSIDE**

The interest in sleep as a site for interaction is its converse relationship to the functional, the programmed and the optimised. Interactivity is thought through action. When engaging with computed environments we are sited within an endless call and

response of action and interaction. Ubiquitous computing promises more indirect manner of interaction. Here, the background becomes the place for an invisible tracking of behaviour, a merging of action and interaction within the digital and the physical. Sleep presents us with an other user model. Sleep is often thought of as a place of non-action. Until the 1950's, most people thought of sleep as a passive, dormant part of daily life. Nevertheless, sleep is in fact a dynamic activity that involves the brain, breathing and blood systems, and muscles amongst others. Moreover, sleep affects the daily functioning of people's physical and mental health in many ways, some of which research is just beginning to understand. What are the actions of the state of sleep? How can computation enter this dormant place?

*Listener* engages the action of sleep through the site of the bed. Where the architectural traditions of the bed and the bedroom is rich in its convoluted understanding of the intimate and the social a modern reading of the bed has become linked to a sense of isolation and solitude. As a place the bed is understood as an intimate space of bodily presence, but it is also inert, unconscious and closed. As a place the bed is the site of the non-programmed and non-optimised. The bed as a site draws inspiration from early artistic works such as the 1963 film *Sleep* by Andy Warhol [8] and the 1980's installation *The Sleepers* by Sophie Calle [9] Although very different from one another, both works exemplify the curiosity we have regarding the action of sleeping, and the desire and inability to capture its essence.

In *The Sleepers* sleeping becomes communal. Calle invited about 30 people to continually occupy her bed for 8 days. Her objective is not so much as to perform in front of an audience, as she herself worded it in the opening of the book *The Sleepers*: "...creating arbitrary situations that take the form of a ritual". Recording the recurring ritual of sleep and falling asleep is what *Listener* does. But where Calle's work treats the question of temporality and memory in respect to the characters of its occupation, the persons that in fact engage with the bed through sleep, *Listener* remains unoccupied. For Calle the occupant is the enactor of the ritual. It is the thoughts of the sleepers, her relationship to them as well as their physical imprint of their body postures and the bed sheet that present the repetitions, the rhythms and the rituals that is sleep space.

*Listener* has a more introverted measure. Here, it is the pulse itself, the shaping of its breath and its continual re-enactment that is the shaping of the work. Visitors to the installation engage with *Listener* through its mounting on a bed sized plinth on which it heaves its heavy breath. As such, *Listener* remains in a more diagrammatic relationship to the bed, pointing to the bed as a site of activity, a place of occupancy that while released from the directly programmatic has its own ritual habits and cultural practices.

It is a parallel interest that informs our interest in Andy Warhol's *Sleep*. As Branden W. Joseph argues, *Sleep* is highly influenced by John Cage's music and Marcel Duchamp's artwork, using repetition as a form of difference [8] Joseph identifies that Warhol devoted much of his attention to repetition in his painting of that same time. In his close account of the film's unfolding, Joseph asserts that *Sleep* uses both shooting techniques and editing effects to enhance the impact of repetition. By filming a man sleeping for little less than six hours, the film's repetition eventually collapses the association of death and eroticism; through a compulsive repetition where we reach a point where everything changes and becomes singular. In continuation to this

reading of *Sleep*, the choice of sleep as the domain of action for *Listener* identifies sleep as an action that readily lends itself to the question of repetition. *Listener* in itself attends to the issue of repetition as a patterned textile surface capable of incorporating none repetitive segments as well as repetitive ones, with relation to questions of programme, proportion, material and interaction.

## 5. PERFORMING TO A BLIND MEASURE

The site of sleep provides a sanctuary for *Listener*. Rather than defining the performance of the material in respect to an idea of optimisation, of structural strength or interactive agility, *Listener* finds its own subconscious rhythms, responding to the realm beyond it while inadvertently negating the fundamental measures of both architectural programme and digital culture. In *Listener* the material performs to its internal logics, defining its own behaviours as it inhales and exhales. Where the membrane is defined stitch by stitch in a hyper specified surface its relationship to use remains open. Still awaiting the full potential of its investigation, *Listener's* blindness towards programme corresponds to the open endedness in which Anthony Dunne sees the interaction between people and designed objects. Cultural complexity then unveils the poetic aspects of design.

In Hertzian Tales' *Faraday Chair* and *The Pillow*, Dunne and Raby are using the site and the objects of sleep as a way to exemplify electromagnetic influences over inhabited and urban spaces. These works represent two extreme conditions; the former creating a shelter from electromagnetic influence, providing a safe haven for sleep, the latter tracing the presence of radiation in the interior of a transparent pillow; the pillow is representing the most vulnerable place where we rest our head. In his book *Hertzian Space*, Anthony Dunne suggests that everyday electronic objects "dream" rather than be "smart", by leaking electromagnetic waves well beyond their perceived boundaries. He writes, "If the electronic object has a role in humanizing Hertzian space it is not as a visualization or representation of radio but as a catalyst, encouraging the poetic and multi-layered coupling of electromagnetic and material elements to produce new levels of cultural complexity". Dunne and Raby document *The Pillow* at the feet of an elderly woman who "adopted" it as her pet after her own had died. This, according to an interview with David Womack, is to challenge the idea that design is exclusively geared towards solving problems. Rather, what they are after is the negotiation between people and objects in a way that extends beyond the designers' initial intention. Furthermore, this creates a poetic interaction, and facilitates rethinking of social connection and everyday experiences [11].

This account of the making of material probes leading up to the design investigation *Listener* is still very much an ongoing experiment. Its realisation in part has enabled us to push forward and better perform the design process of a highly specified, customized knitted surface, in itself a reflection to our interest in architectural making. The interconnectedness between the different aspects that make *Listener* what it is, such as its geometry, materiality, behavioural attributes and computational characteristics are built into the logic of its fabrication and present a flexible model for design. Yet it is still questionable how and whether *Listener* dreams, and to what extent is its functionality "to

listen" is fulfilled. Locating *Listener* at a bed side, a site of multiple social, cultural and historical interpretations has proved to provide a myriad of opportunities for *Listener* to farther gain its specificity.

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