PLANKS: A Computational Composite

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ABSTRACT

What is a computer in interactive architecture and smart materials? How can we articulate the computer in order to be in sync with the design space it populates in these contexts? The design experiment presented here entails creating a physical manifestation of a computational composite–a concept used to articulate the computer as a material for design. The experiment is meant to explore part of the expressional landscape available through this material composite perspective. In the experiment, it is especially the computers ability to redefine established cause-and-effects between materials and their environments just as it is the computers ability to create a discrete dependence on contextual factors installing an explicit element of temporal form, which are explored.

Categories and Subject Descriptors

J.5 [**Arts and Humanities**]; B.4.2 [**Input/Output Devices**]

Keywords

Computational Composites, Design, Experiment, Expressions, Materials, Wood

1. PROBLEM STATEMENT

"Technical knowledge and language are the well from which design and invention draw stimuli for planning. And they are also the basis of the organization of means that constitute the practice of design." As Manzini write in his Material of Invention [11, p.47]. While technical knowledge and language of the computer are necessary to be able to incorporate computers in any design practice, the computer can be articulated in many ways and it can even be many things all dependent on the point of view.

Computers in a design context are often portrayed as *elusive* and *abstract* elements, which also can provide a multitude of functionality (c.f. [10, 13, 16, 18]). However, this dissociation of the computer as an always and ever *physical* element, which builds on a simple set of principles that are just multiplied into complexity, is problematic and unnecessary. It is problematic because it creates a promise of accessibility to symbolic logic without constraints as well as an unrestrained form-language neither of which exists. It is unnecessary because it is possible to develop a set of concepts to describe and explain the basic properties of the computer as a material for design and through that address new expressions of computational technology. For a successful design practice with computers the discrepancy between *what is* and *what we say is* cannot become too wide. The articulated design space must somehow be coherent with the actual one.

Articulating and understanding a technology in different ways is about emphasizing and playing down different aspects of what it is. It is necessary not to get lost in technical specification when they are not immediately relevant, and not to be tangled into an application domain when developing technical details. There is a division of labor and consequential a division of language and knowledge within every genre of technology. Take textiles: specialized engineers research and develop fibers, materials, and production techniques, which textile designers utilize in their work designing new textiles. Fashion or industrial designers in turn use these textiles to create clothes, furniture, or art. Through this process of textile design and use the goals and methods are not the same, and therefore the knowledge and the language are not the same either. The textile engineer works on a highly theoretical basis, yet she never escapes the physical and tangible aspects of her work field. The clothes designer primarily works with the sensory experience of the fabric and needs to know little about the material fibers and production, however, she cannot be completely ignorant if what she makes should last or be practical. Furthermore, the articulation of a textile is never just a technical specification; it is always accompanied by either the textile itself or by an experience with similar textiles. Therefore, knowledge and language of textiles or any other design material cannot be expressed through words alone. Doing that risk causing misunderstandings or even worse, lead to an abstract rendering whereto no one can relate. Articulating the computer as a material for design is not done by developing a conceptual framework–we need *physical samples*.

This paper explains the concept of computational composites–a concept articulating the computer as a material for design. Following this is an outline of an experiment in which we build a physical manifestation of a computational composite that explores new expressions of computational technology. Summing up is an analysis of what the experiment could lend us particularly in relation to a design practice involving computers in architecture and design.

2. ARTICULATING COMPUTERS

Articulating the computer as a material for design is about describing it through the characteristics of other design materials not as a metaphorical exercise, but as a perspective to help guiding what needs to be emphasized and what is less important. The computer in this context is not a machine for symbolic logic nor is it information technology ready to use–it is somewhere in-between and yet far of. It is the computer's physical being, which constitutes the foundation for understanding the computer as a material for design.

While the computer is physical through and through it is not enough to see it as a substance to understand its potential; thus, some basic theoretical knowledge about its structure is needed to be able to utilize it for design.

A computer's main substance is electricity. It is made useful through managing two extremes of electrical potential measured between two points of a circuit, one as close to zero as possible and one above a certain threshold. A build-in clock controls the timing of each measurement. The computer can operate with sequences of high and low voltage through the use of registers. The structure of the circuits enables basic logic operations such as AND, OR, NAND, NOR (see Figure 1). Combining these operations and the storage capabilities allow highly complex computations. Therefore, the computer can perform complex conditioned actions based on fairly simple principles.

INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

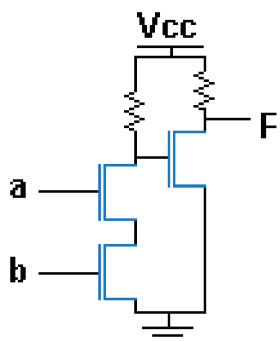

Figure 1: Example of a circuit structuring the logic AND operation–only if both a and b are high (represented by 1) will the circuit measure a high voltage level, courtesy of Wikipedia

This structure results in a surface of the computer, which consists of an acceptance, and a transmittance of these high and low voltage measures. Traditionally, materials are perceived to have a clear and recognizable surface. However, the border between the material and the environment is in fact less demarcated [1]. The exchange of chemical components (e.g., oxygen causing corrosion) or the change of conditions in the immediate environment (e.g., a rising temperature causing change of color) exemplifies that the surface is better thought of as active zones or as actions [1]. This perspective corresponds with the surface of the computer in which the exchange of different levels of voltage constitutes its "active zone."

Yet, the surface of a computer is barely physical and unquestionably hard for any person to interact with directly. And while the computer in theory can do all the complex computations, we would find it difficult to relate to them as a material for design. However, except for the Turing machine, we hardly ever hear of a computer in and by it self and this is the key to approaching it as a material for design. In a previous paper [17] Redström and I found that composites–in which several materials are combined in one new material to provide a new combination of properties (c.f. [8])–can be how the computer becomes a material for design. Accordingly, the concept of *computational composites* refers to an assemblage of materials in which one is a computer. Also, the assemblage must be combined in a way that utilizes the computations in the composite's expressions. Yet, as a computational composite the computer becomes a kind of the so-called smart materials.

To design a composite material is generally about choosing a set of materials with properties, which would compliment each other and through structural and/or chemical conjunction form a new material [8]. The tradition of composite materials design allows the use of production methods, glue, as well as structural remedies to combine the material components. In the project reported here, we are interested in exploring the primary property of computers–their ability to compute–and what that means in a material context. This consequently becomes their ability to control transitions between states in something else and let that be dependent on events outside the computer. And this perspective is important to keep in mind when designing with computational technology. For the computations to come to expression, however, the other components of the composite must be resilient to oscillation between states and possibly sensitive to changes in the environment either near or distant.

The resulting properties of a computational composite are–as with any other composite material–inextricably related to the properties of its components. A computational composite, however, is always able to be in one of two or more states and to change between the states based on a set of designed conditions. These conditions can either be designed with a closed data set, or they can take in measurements of an environment. Furthermore, where most traditional materials change expressions over time–often referred to as patina–computational composites changes between states as a controlled reaction to the conditions.

A computational composite will always contain some transformation of energy, and at some point the energy will have an electrical form. Most often computational composites need an external power source, but sometimes it can be built into the material composition (e.g., through solar energy panels or windmills). The energy transformation can happen within smart materials (e.g., shape memory alloys or nickel chromium wires) or through special actuators (e.g., motors or solenoids). The changes in the environment also need to be measured and transformed into a form, which the computer accepts. This can be done with various buttons or through complex sensor technologies designed to deliver input to a computer (e.g., measuring proximity or humidity). The transducers needed to transform the energy through out the material may not make a computational composites seem like a material, and perhaps we would even have a tendency to name them machines, however, we claim that it is partly a matter of scale and partly a matter of technological development. There are several smart materials on the market with a machine like behavior only this behavior happens at a molecular level and therefore not accessible to laymen including most designers (e.g., self-cleaning clay tiles or glazing with integral sun control louvers [2]).

Computers are used as a material for design whenever they are used in products and environments. Even if they are not thought of in that way computers are used to make other material elements behave in a certain manner. The concept of *computational composites* provide a way to understand the mechanisms of the computer, its properties, and especially its relation to other materials. *Computational composite* offers a perspective that addresses the computer and its properties for design and depicts its uselessness as an independent element. Even if the computer in a context of an object or thing may not take on the form of a computational composite because all the elements in the product are interwoven and talking about composites consequently would be meaningless the concept still allows us to understand the relations between computers and other materials. Just as importantly, the concept inspires to design a new middle layer of computational materials for others to use in their designs–parallel to how textiles are used.

3. EXPRESSING COMPUTATIONAL COMPOSITES

Thinking of the computer as a material allows a new range of potential expressions. A material's potential expressions rely partly on its inherent properties and partly on the environmental conditions (including the social context). Most of the properties of computational composites, as a general class of material, can be delineated based on the theoretical articulation, but some needs to be learned through creation, experimentation, and physical manifestations just as any comprehensive communication of a new material must rely on more than the written word.

Creating a physical manifestation of the concept of computational composites could take on many directions. Thus, to pursue a path, which will enable us to learn more about the potential expressions of computational composites, we have formulated a design brief setting up some boundaries and goals for this specific experimentation.

1. The project should work with expression before function, building on a concept and a leitmotif proposed by Dunne and Hallnäs & Redström respectively. Dunne's [3] concept of *Parafunctionality* is an approach that enables the design of something seemingly familiar but with an angle that allows provocation, surprise, or dysfunction, which removes the focus from the efficiency of the design towards its aesthetic expressions. Hallnäs & Redström [6] operates with the leitmotif "functionality resides in the expression of things," (p. 166) which encourages the designer to take the expression seriously and even work with expressions first and through that invite experimentation around new functionalities.

2. The expressions explored in the project should go beyond those visually perceived. The emancipation of the computer from the constraints of information technology also includes a demonstration of how the computer can integrate material expressions that rely on a more complex sensory experience. The richness of expressions expands dramatically when taste, listening, smell, touch, and the body's sense of space become part of the vocabulary for computational design [14].

3. The explored expressions should also explicitly reflect the computational composites strongest property: a controlled oscillation between two or more states.

4. Finally, the result of the project should be recognized as a computational composite. Meaning that it should hold strong references to acknowledged materials and it should in theory, if not in praxis, could be mass-produced and used by others to design something from. If this point fails, the attempt of a physical manifestation articulating the computer in a new way has been unsuccessful.

There are several ways into this project, and almost every choice has been made and refined in a dependence on other choices. The following description, therefore, takes an offset in the strongest denominator for the result–the choice of material, which constitutes the other main part of the composite material. For this we choose wood.

Figure 4: A Grete Jalk Chair from 1963 made from two pieces of plywood bend into shape

Wood is strong compared to its weight, it is flexible yet hard; it is durable and sustainable [4]. Wood changes in appearance and strength over time usually resulting from environmental conditions. Wood is a natural material and is often used sliced as timber or carved into form. Wood, however, is also common as engineered material where wooden strands, particles, fibers, or veneers are bound with various adhesives known as plywood, Masonite, or MDF (Medium-Density Fiberboard) [7]. Engineered wood is popular in architecture

Figure 2: A close-up of the PLANKS each bending outward when touched by sound and straightening when in silence.

Figure 3: First picture shows the PLANKS in action. Second picture shows a close up of the computational layer and the "adhesive layer" including the motor (Unfortunately, the prototype illustrated here turned out to have a construction error and it only worked for a short while. New ones are being build.)

and design due to their strength, their plasticity, and their low cost.

The inspiration for this project comes more specifically from plywood. Plywood was developed to give new dynamics to wood (see Figure 4). Plywood comprises an uneven number of layers of veneer (typically five) glued together cross grain. The grain in the surface has the same direction, which allows a high flexibility in shaping the wood into bend forms because the other layers ensure the strength[7]. Others have done projects inspired by or directly using plywood, take EL Plywood [9]; for example, in which the Kennedy and Violich studio utilize the layers in plywood by embedding flexible circuits between the sheets of wood giving them the possibility of dynamic illumination directly at the surface of the material.

In this experiment, we want to provide wood with another type of dynamics–that of temporal form (Others have explored the temporal form as an inherent effect of computations c.f. [5, 12]) a dynamics in which the wood can oscillate between two or more states. Yet, we want to explore expressions that are more than just visual effects. We seek expressions that will be ”measured equally by the eye, ear, nose, skin, tongue, skeleton, and muscle” [14, p.41] as Pallasmaa describes the experience of qualities of space, matters, and scale in architecture. Such expressions will partly rely on the memory of previous experiences with similar materials (e.g., the taste of a material is an experience primarily acquired during childhood c.f., [15]) but primarily, of course, on the current design. This makes us work with expressions dependent on changes of shape and size, of texture, or even of presence, and to include the whole body in the experience. Furthermore, such changes of shape, size, etc., needs to be of a significant volume to have an impact.

The flexibility and durability of wood inspire us to let thin planks of wood continuously move between a bent and a straight shape. We borrow from the layering of plywood to articulate the layers of this composition where one layer is the computer, another is the ”adhesive” in form of a motor, which transforms the computations into movements in the planks, and the final layer will be the plank itself. This expression will emphasize the physicality of computers and take the dynamics of plywood a step further. However, we have not yet established the design of the computations nor the environmental conditions, which it might depend upon.

Computations can be used to emphasize, transform, delay, and otherwise manipulate any natural or established cause-and-effect. So while the expression of any material is dependent on its inherent properties and the environment, the design of a computational composite provides an opportunity to more explicitly design how the material should react to the environment and, for instance, bring in a more poetic dimension to the expression. Traditionally wood is affected by humidity, temperature, light, and to some extend wind, which can make it shrink and expand; grow week or rot; bend or break, as well as change color. However, the elusive flow of sound waves is known only to cause small vibrations in wood, i.e., in a wooden guitar. This expression, we will emphasize playing on a synesthetic effect were sound waves are no longer amplified, instead, the oscillation becomes perceivable to the body through larger scale vibrations or waves in the planks. The planks become hypersensitive to sound.

The sound sensitive waving planks are deliberately different, yet we name them PLANKS to emphasize their relation to the established assortment of wooden materials (see Figure 2).

3.1 PLANKS: Technical Specifications

The composite is made in the shape of two-meter long planks. The components of the PLANKS are organized in three layers. The surface layer is responsible for the outward expression and comprises a 8mm thin untreated plank of pine and an electrets microphone (see Figure 3). The ”adhesive” layer transforms the impulses from the computer into the surface layer. The ”adhesive” layer comprises: a structure to carry the construction, a servomotor, a switch, metal gearing, wiring, a threaded rod, and bolts. The third layer is the computational layer and comprises a small computer equipped with a simple algorithm, a microphone amplifier, a potentiometer, and wiring (see Figure 3).

Each PLANK functions individually. The computations are designed so they activate the servomotor when the microphone (through an amplifier) generates a change in voltage that is above a certain threshold. The threshold is adjusted through a potentiometer to fit the actual context (thus, the context sensibility is tuned through an input to the computer which basically is an adjustable resistance). The computer will allow the servo motor to run for a couple of seconds equivalent to pushing out the surface plank a couple of centimeters. As soon as the motor stops the computer will again react on voltage measures from the microphone. When, however, there have been a silent for 10 sec the motor is triggered to rewind–again for a couple of seconds. If the measurements continuously are above the threshold, the surface plank will continue outwards until it reaches its maximum at approximately 25 cm from the straight position (a measure tested during construction and defined within the computer individually for each PLANK due to small construction and material discrepancies) the motor will not be activated even if there are sounds above the threshold instead it will wait a couple of seconds before ”listening” again. A PLANK reaches a minimum when it is straightened sufficiently to turn off the switch mounted at the construction layer. At the minimum position it will start listening again. The PLANKS are dependent on external power supply, however, up to ten PLANKS can be supported by the same 12V power supply.

The PLANKS composite comprises a negotiation between each element (or material) and it is this negotiation, which makes up the properties of the composite. Properties which are different from the sum of the properties of the parts–some are restrained (the computer) and others are challenged (the pine planks). Furthermore, several PLANKS together will not react in unison because of the small differences in the materials and construction adjustments as well as the individual placement of the directional microphones. Several PLANKS together will, however, react on their neighbors–more specifically on the sounds made by the others' motors–resulting in a dynamics apparently unpredictable and autonomous. The PLANKS are not in production. While this would take quite some sophistication of their structural design, it would more importantly be beside the point. The PLANKS are meant as a material for reflecting upon design with computations and the possibilities they present.

4. DESIGNING WITH COMPUTERS

Designing with computers requires an understanding of what they are made of, what they can do, and especially how they connect to their surroundings. Computations are indeed invisible to the eye and even the rest of our sensory system. Nevertheless, they do have a physical existence. Hence, if we want to use them for design we need to know their results relates to other materials. To give form to computational things or objects is then perhaps not a matter of packaging (c.f. [3, 12]), but a matter of forming the computations in combination with other materials. Materials that are capable of receiving the desired input and expressing the results of the computations in a suitable set of states.

In architecture, materials are used to make space and define volumes. Computational composites are through their explicitly active surfaces capable of changing volumes and blur space. The PLANKS used as a high panel in a room would, for instance, create a space of changing volume. As the volume of sound increase in the room the volume of space would decrease. Or a door made of PLANKS could provide cracks for visitors to peep through if they said ”sesame.” The suggested ”uses” of the PLANKS may seem a bit off, but that is exactly the point. The PLANKS are designed to lend insights into computational composites and through that the potential of computers as material in design.

The PLANKS are physical manifestations of the concept of computational composite with an emphasis on the expression and a negligence of any practical use. The PLANKS represent a combination of properties from wood and computations resulting in an untraditional expression of both. The layering of the material enables a focus on the individual components and how they are combined while the surface still allows an experience of the aesthetics of the expression. The layering is also meant to emphasize the possibility of replacing one layer with another and thus achieve in a new composite with a new expression.

The PLANKS represent a material where the computer is used to redefine a cause-and-effect known from nature. The computer interprets the sound waves transformed through the microphone and uses them as triggers causing a state change in form of a reshaping of the PLANK. Furthermore, the computer is used to establish an explicit temporal form. The expression of a PLANK is discretely linked to the context, and thus the expression changes over time as the context changes. The temporal dimension makes computational composites a type of material with a strong characteristic of becoming–it comes into being in context.

The PLANKS are an attempt to articulate the computer–to show that computers exist as a material for design and that this entails an understanding of the computer as a physical element. That all computing is ”physical computing” even if our most common interaction with computers appears symbolic. Additionally, the PLANKS are an attempt to explain the relation between computations and how they connect to other materials as well as it is an exploration into the potential expressions of computational composites as a material for design. Lastly, the PLANKS should help delineate a space of computational design, which is more coherent with the actual potential than any story of immateriality and virtuality.

5. ACKNOWLEDGMENTS

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