ABSTRACT
Advances in the creation of computational materials are transforming our thinking about relations between the physical and digital. In this paper we characterize this transformation as a “material turn” within the field of interaction design. Central to theorizing tangibility, we advocate supporting this turn by developing a vocabulary capable of articulating strategies for computational material design. By exploring the term texture, a material property signifying relations between surfaces, structures, and forms, we demonstrate how concepts spanning the physical and digital benefit interaction design. We ground texture in case study of the Icehotel, a spectacular frozen edifice. The site demonstrates how a mundane material can be re-imagined as precious and novel. By focusing on the texture of ice, designers craft its extension into the realm of computational materiality. Tracing this process of aligning the physical and digital via the material and social construction of textures speaks back to the broader field of interaction design. It demonstrates how the process of crafting alliances between new and old materials requires both taking seriously the materialities of both, and then organizing their relation in terms of commonalities rather than differences. The result is a way of speaking about computational materials through a more textured lens.

Author Keywords
texture, interactive architecture, interaction design, tangible interaction, computational material, Icehotel, Sweden, design theory, architecture

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

General Terms
Design, Theory

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

TEI/10, January 24–27, 2010, Cambridge, Massachusetts, USA.
Copyright 2010 ACM 978-1-60558-841-4/10/01...$10.00.
We ground our conceptual exploration of texture through a case study of the Icehotel. The case serves as a strong example of design conceived around one basic material. Made completely from ice, the focus in crafting this setting is the process of transforming a material’s meaning, organizing new communities of designers and users to utilize the material, and then extending the material into relations with other substrates, whether physical or digital. As such, this particular case serves as conceptual grounding for imagining how relations between materials, and thus textures, might guide the development and evaluation of tangible and embedded interaction designs.

The paper concludes by discussing how texture generates research directions at the intersection of computing, materials science, architecture, and art. Ultimately, crossing the final divide between atoms and bits requires finding the language to describe both traditional and new materials as part of a common world.

RELATED WORK: THE “MATERIAL TURN” IN INTERACTION DESIGN

Multiple streams of research and design suggest that the question of relation between the physical and digital has given rise to a fundamental and basic concern for materials within the context of computing. Ubiquitous computing, tangible interactions, and computational materiality represent strategies for accomplishing full integration of the digital and physical.

Mark Weiser’s insight, that computers might be seamlessly integrated into the world, marked an important overture in what might be called a “material turn” [21]. By decoupling computing from the computer, ubiquitous computing made visible new strategies for bridging the digital and physical. No longer tied to a specialized device, computation could extend into everyday life by aligning with material and social practices already underway. At its best, ubiquitous computing motivates a design sensibility that gives rise to new ways of thinking about the aesthetics of calm computing. At its worst, it creates an aesthetic of disappearance that generates a host of other questions about the way that we design interfaces and make visible computation.

Growing out of insights about the potential for bridging the physical and digital, tangible interaction diverges by cultivating a different sensibility in its strategies for design. Creating analogues and metaphors to negotiate between the physical and digital, tangible interaction has given rise to graspable media [9], metaphors [11] and toolkits [12] for bridging the divide. However, by relying on strategies for mapping via analogues and metaphors, tangible computing inadvertently invests in maintaining the separation in order that they might cross the divide. Moreover, metaphors and analogues, by definition, operate a level up from the basic materials themselves. From this vantage it is difficult to ask what was always already in common between the physical and computational.

Growing interest in the materiality of computation signifies a shift in the modes of strategizing bridges across the physical-digital divide. This, we believe, is a “material turn” in interaction design. Recent works demonstrate the desire to begin treating the computer as just another material. Bdeir gives voice to a more general interest in “bring[ing] electronic devices down to a material used in the design process by imagining electronic parts on the same level as paper, cardboard, and other materials found in design shops” [1]. No longer content to rapidly prototype the computational with the non-computational, the designers are moving towards stripping away distinctions altogether. Similarly, Vallgård and Redström [19] read the computer as a material, analyzing the substances from which it is made, its surface, and structure, and then utilizing these properties as a springboard for discussing the potential properties of “composite computational materials” similar to the concept of “transmaterials” [2, 3]. This shift in the prioritization of the computational as material indicates the emergence of an aesthetic position remarkably different from that of the Weiserian vision of ubiquitous computing, with its regard for pushing the computational towards absorption into the physical world.

Similarly, a range of everyday materials like felt [17] and clay [16] are being re-imagined as substrates that can be invested with computational properties. The result is an activation of properties, always already there, that can be interacted with and experienced in wholly new ways. Researchers are beginning to consider how a range of new materials – from shape memory alloys and fabrics to smart fluids that deform when exposed to current – might transform interaction design. This trend indicates a kind of communal reaching towards a vocabulary for describing the management of material properties within a computational framework [10].

Explicit theorizing about computing through a material lens is beginning to surface. On the one hand, Löwgren and Stolterman suggest that information technology is in fact a material without properties [13]. As pinpointed by Vallgård & Redström [19, 20] that would paradoxically make it hardly qualify as a material. But, from Vallgård & Redström’s perspective what Löwgren and Stolterman are hinting at is the way in which information technology seems to exist in-between the material and the immaterial, with properties so flexible it almost can take on any form imaginable.

By shifting away from metaphorical or analogic strategies of relating the digital and the physical, designers are beginning to address more basic material properties across a broader range of substrates. This more fundamental treatment has proven rather powerful for generating new design insights at a variety of scales, including the architectural. Shutters [8] a computational re-design a common building element, louvers, is not merely another example of embedding digital functionalities within a
traditional object. Shutter materializes the interaction design concept of “soft mechanics”, a move away from hard structural joints and towards soft forms. By viewing the architectural in the context of computing, they re-
consider as well the material properties of the originally material form. The result is a new kind of re-forming texture for apertures on louvers.

Urban pixels [18] re-order the night-time cityscape by attaching to any surface and re-shaping the skyline. The BIX Matrix, an electronic “skin” covering the Kunshaus Graz art hall in Austria, the SPOTS low-res digital- façade at Potzdammwe Platz in Berlin, Germany, or the Light BRIX, a physical wall of virtual bricks function as facades that actively participate in the architectural presence of urban centers [4, 5, 6]. Even the Eiffel Tower has been re-

invigorated with dynamic, blinking lights as a mode of re-
shaping structures through the addition of digital elements.

Borders between surfaces and interfaces are blurring,
sometimes disappearing completely, and creating new experiences of the built environment as crafted from computational materials. We now require a repertoire of concepts to scaffold our thinking about how basic materials could be re-de-signed through the addition of computational power.

We argue that the overall research approach and strategy here might be interpreted as a broad reconsideration of materiality within the context of computation. In doing so this paper contributes to this body of knowledge by taking a single concept about material relations, i.e. texture, and exploring how it might be used to design across the physical-digital divide. Not motivated for the purpose of bridging attempts but rather as a new approach, the notion of texture does not assume any divide at all. Offering a new perspective on fundamental material properties contributes to an emerging area at the intersection of tangible interaction, smart environments and interactive architecture. Because texture refers to relations, not disruptions, it is not a term that minds the gap between physical and digital materials. We argue here that there is a complementary mode of viewing the relation between physical and digital that becomes apparent when we shift our lens towards a concern for what kinds of properties different material possess. Then the design space becomes concerned with modes of relation between these properties, a concept we call texture.

MATERIALS AND TEXTURES
As to advance our capabilities of imagining what kinds of new materials, relations between materials, and interaction with new materials, are possible at a range of depths—from interface to structure, and across a variety of scales—from object to architecture we also need a well-grounded understanding of the properties held and sensations caused by the surface of material objects received through the sense of touch, i.e. a good understanding of texture.

According to the Oxford English Dictionary, texture refers to the feel, appearance, or consistency of a surface or substance, the character or appearance of a textile as determined by the arrangement and thickness of its threads, the tactile quality of the surface of a work of art, and the quality created by the combination of the different elements in a work of music or literature.

Although texture has its theoretical roots in material science (see [15]) it has been applied to diverse areas including geology (describing the physical appearance or character of a rock), food (concerning the way food feels in a person's mouth), and cosmology (as a type of theoretical topological defect in the structure of spacetime).

The concept of texture has certainly been employed in a more metaphorical register as well, often used to describe the “feel” of non-tactile sensations. In painting it has been applied to describe the feel of the canvas based on the paint used and its method of application, i.e. as a way of addressing an effect or consequence of the material.

We use the term “texture” to refer to the intersection of surface and structural form. Articulating this term speaks to a gap in the current literature related to organized thinking across material, digital space, or physical and symbolic representations in a manner useful both to new materials and tremendously old ones to help preserve the sense of experience.

Texture refers to “the feel, appearance, or consistency of a surface”. The emphasis on the experience of a surface resonates with contemporary phenomenological understandings of the user interface in the area of HCI. “Feel” refers to immaterial aspects of a surface. “Appearance” refers to the way in which the underlying infrastructure is communicated to an observer. Finally, the concept of “consistency” is two-fold. It addresses both the consistency of the material itself as well as the way the material is used elsewhere in the environment, or how it integrates with other textures to create a sense of “wholeness”.

While we could conduct a straightforward application of texture to digital objects or tangible user interfaces, we believe this line of thinking suggests a gap in computational versus non-computational materials that we do not support. Instead, we argue that it is critical to understand that digital technology is already contextually situated. Tangible and embedded interaction, constituted with and through basic and natural materials that have been scaffold or transformed through digitalization can be read alongside any other material. Digital technologies are textured, they are part of the materials that surrounds us and constitute our built environments.

Building on this reasoning we propose textures as a construct for interaction design. Texture is an irreducible characteristic of any material (including “new tangible
computational composite materials”). It is central to our experience of materials in everyday life. We understand texture 1) in relation to “the real” materials as they form new structures and elements that gives us full scale built environments and 2) as a concept which addresses the way we perceive and experience our surrounding as a meaningful whole. It is when elements come together as textures that we can read, interact, and relate with the physical world. Finally, we take the perspective that we interact with and through the materials, digital or not. This basic conceptual construct brings together a “hard science” perspective on texture (material science, architecture) with the “soft sciences” (focusing on e.g. experience, affect, and feel) for the purpose of understanding material compositions as meaningful textures for interaction. In the next section we move forward from this conceptual model to an empirical case study of the Icehotel in Sweden that demonstrates this perspective as an analytical tool.

CASE STUDY: ICEHOTEL

Two hundred kilometers north of the Arctic Circle, in a remote landscape dominated by darkness and long winters lies Sweden’s most popular tourist destination, the Icehotel. For twenty years the frozen edifice has served as the nexus for convening international teams of artists, designers, engineers, and architects. Together, they transform the mundane substances of the tundra—snow and ice—into remarkable materials for contemporary design. The result is a spectacular architecture, more than 5500 meters square (59,209 sq ft), filled with ice suites, ice rooms, ice galleries, an ice church, and ice bar. Every setting is completely decorated and furnished in frozen water. This Arctic architecture provides a strong example study for thinking through computational design precisely because the question of materiality, something central to tangible interaction, lies at the heart of its design.

De-sign: Transforming Material Meanings

Icehotel’s rather uncanny position as Sweden’s preeminent tourist destination represents a remarkable transformation in the international visibility of this remote region. Created by Jukkas, a local tourist operator, Icehotel strategically inverted tourism. Rather than marketing the region as a “Land of the Midnight Sun” they set about re-imagining long winters, relentless darkness, and temperatures below -30 C (-22 F) as attractions. Literally inverting the relationship between tourism and season involved recruiting the landscape, materials, and understandings about the north into precious commodities. The problem of shifting perceptions maps to a common aesthetic concern in ubiquitous computing: the need to strip a particular concept, the computer, from its current form, the device. By exploring potential strategies for decoupling relationships between material and meaning, a process we label de-sign, the case makes visible how cultural resources might have been leveraged to successfully shift a material into a novel configuration.

Though not traditionally regarded as a premier site for tourism, the region does not lack for associative meanings. The “Far North” has always been a powerful metaphorical construction, fueling the literary imagination and standing in as a metaphor for personal transformation. For over 400 years the area has served as a setting for Jokkmokk, the annual trading and tribal parliamentary gathering of the indigenous nomadic population, the Sami. In this sense, the space carries the strongest local meanings precisely in the region’s coldest darkest months.

Additionally, the Arctic has become increasingly positioned at the forefront of debates about climate change. The municipal district of Icehotel, contains over 530,000 hectares of national parks, nature conservation areas and animal sanctuaries; 11% of all the protected nature in Sweden lies within this district. In a part of the world still fed by glaciers, where water in every stream is potable and access to nature unfettered, the landscape has become increasingly precious. In fact, Northern Scandinavia is frequently marketed as “Europe’s last wilderness”, a framing that creates a certain cultural cachet for northern winters in an era of global warming.

The presence of an indigenous nomadic culture coupled with access to the vast unspoiled landscape makes possible a kind of discursive re-framing of the setting as a site for eco-tourism, akin to other areas of the world like Costa Rican rainforest, or Serengeti plains safari operations. What distinguishes the Ice Hotel, however, is the way in which the encounter with the region has been designed through the transformation of a mundane material: ice. Changing a material’s meaning requires addressing not only its surface, but its aspects as a whole—both structural and cultural; building displays from wood, without addressing the material’s meaning, produces clever kitsch, but hardly long-term, sustainable meanings.

Material Communities

Icehotel is by no means the first or only frozen architectural attraction. What makes Icehotel extraordinary is the way it concentrates thinking about a single material transformation. This material thinking requires active social work by producers and consumers. Together, they invest the textiles that they experience with new cultural meanings. In so doing, the space enables particular ways of thinking about spaces of relations between computing and physical materials, architecture and technology.

Each year international teams of artists, designers, architects, and engineers convene on the site, working together to realize creative projects rendered in snow, ice, and increasingly electronic and light-based elements. Some participants come for the first-time. Others come every year. Together, they create a structural shell scaffolded by steel space frame. Once complete, artworks, rooms, furnishings, decorations, and ornamentations follow suit. By focusing on a single material a space of total immersion
within its textures and properties can be created and explored.

The ritual return coupled with the assemblage of distributed practitioners helps cultivate a community invested in a new technological process, and thus committed to making visible the value of the Arctic region. As cultural entrepreneurs, artists and designers demonstrate how a ubiquitous material can be transformed into a cultural work. Much like early iconic projects in ubiquitous and tangible computing (e.g. Natalie Jeremjenko’s *Livewire*) new technologies and processes must be made visible to end-users in order that the might imagine the potential for properties of digital information to work within a material world. Simultaneously artists’ professional identities as craftsmen become enhanced by their relationship to a new material.

Meeting this network of producers is an equally international network of consumers. Icehotel represents a chance to spend a night in the Arctic Circle protected from the elements by the elements, transformed through ingenuity and design. The popularity of this experience has resulted in daily direct flights from London Heathrow airport to this remote location.

Designing an encounter with the far north through the lens of material exploration creates a concrete form for thinking about abstract notions of the north, winter, sustainability, creativity and design. As a space organized from the same material in a variety of relations and scales, or textures, ritually re-built and re-visited by diverse individuals, Icehotel expands the registers of ice, as a material, and thus opens the possibility of guiding the extension of its relations to other materials, or creation of composite textures.

**Texture: Icehotel X and the re-signing of materials**

Material properties guide not only social and technical practices at the Icehotel, they also shape strategies for producing composites with new materials. For example, a proposed collaboration between Icehotel and Swarovski would have blended crystals and ice, two materials with crystalline structures and clarity. Despite apparent similarities, differences in their relation to time prevented the collaboration from taking place. Crystals operate at geologic scales. Refined by Swarovski they become “timeless treasures”. Ice from the glacial Torne River, however, represents natural rhythms, cycles, flows, and change. To visit Icehotel is to momentarily inhabit a space of frozen time, not to possess it; when Spring comes the ingenuity of its design simply melts back into the forces of creation.

Icehotel does, however, compose new textures based on rather uncanny materials such as magnetite. Solid, opaque, and black, compressed magnetite slabs are formed from the dust of industrial mining waste. Again, a local mundane material is repurposed for contemporary design. During the summers large black slabs and sculptures remain, working as stark contrasts against the landscape. Similarly, Icehotel frequently features compositions with lighting elements and LEDs. Organizing qualities of light and ice always remain at the center of these visions. Only recently, however, has an ice-based structure at the scale of a public space been composed with computation as a central feature.

During 2008 and 2009 we were collaborators on a multi-professional design team charged with creating “Icehotel X”, a full-scale public interactive environment placed in the city center of Copenhagen [22]. The design challenge of “Icehotel X” was intended to communicate “the spirit of Icehotel” in an urban location 2000 kilometers south of its actual location.

Whereas we have in this paper already illustrated how a focus on textures leads into thinking on *de-signing* materials, we now illustrate how an understanding of textures as architectural elements and meaningful compositions of material properties can serve the purpose of *re-signing* materials, bringing back to them meaningful values and ways of understanding and interpreting a material composition although being staged at a remote location from its origin.

Although raw ice was transported from the Arctic Circle to the center of Copenhagen, and then placed in a refrigerated indoor environment approximately 100 m$^2$ (1076 ft$^2$), Icehotel X still did not effectively communicate the experience of encountering the far north. Thus, we chose to texture the environment by integrating digital technologies into the composition. We believed the transparent qualities of ice and the animated luminosity possible via large displays would better evoke the experience of the Icehotel.

Concerned with the relation between ice and computational power we *integrated* these materials into a single composition. We rejected high-resolution displays and high-speed networking in favor of a large low-resolution LED display whose luminous properties better aligned with the qualities of the ice. Although cinematic representations of the far north, streaming videos, or broadcasting literal real-time interaction between the spaces might provide an experience of the Icehotel, we felt these options might detract from visitors’ engagement in their actual location, or risk drawing attention to the computational power and thus turn Icehotel X into a sort of technological showroom.

**Figure 1.** Low-resolution pixel walls (left) depicts abstract representations of the northern lights (center) and open fire (right).
Two walls covered with LED-pixels (see Figure 1) formed an 8 m long and 2.4 m high interactive wall inside of Icehotel X. These “pixel walls” contained bulbs mounted in a grid and spaced 5 cm apart. The resulting low-resolution display (160 x 48 pixels) was designed specifically to support abstract images and animations (see Figure 4). We smoothed the raw pixels by covering them with 4mm opaque plastic film. The resulting installation appeared as a continuous wall of light rather than an isolated piece of equipment (see Figure 2).

With two pixel walls and an ice-based interior in place we began aligning the materials into a desired texture. An early version of the project proposed creating an immersive representation of the north (see Figure 3), but the scheme was readily rejected in favor of a strategy centered on composing the LED light with the qualities of ice (see Figure 2). An iterative design process, carried out by engineers, light designers, and film editors produced a final composition of abstract animation and ice (see Figure 4).

The final composition communicated the spirit of Icehotel by blending ice and computational power. Bringing the raw ice to life meant crafting an environment that evoked wilderness in the north. We included common tropes like open fires, northern lights, blizzards, and glowing stars.

Icehotel X opened to the public in April 2009. Though digital technologies were omnipresent in the environment, visitors awarded them no particular attentions. No one even looked directly at the pixel wall (see Figure 5). Unlike public installations of televisions of large high-definition screens, [14] these displays helped visitors experienced the room. Rather attention on the other persons co-present in this space.

DISCUSSION AND IMPLICATIONS

This paper presupposes that a “material turn” has taken place within interaction design. The rise of computational composites, transmaterials, and interactive architectures indicates that a repertoire of strategies aimed at reconciling properties of the physical and digital are becoming increasingly practiced within design. Talking about composite materials requires finding a vocabulary for referencing properties of multiple substrates, especially as they enter into new relations. We believe texture might be of some use.

Texture supports a regard for digital-physical compositions. It provides a suggestive aesthetic lens for crafting modes of relation between the physical and digital. A departure from the “aesthetic of disappearance” that often characterizes ubiquitous computing designs, the textural aesthetic does not aim for an invisible quality.

Rather, it advocates investigating the range of properties exhibited by digital and physical materials and crafting compositions from their relation. These compositions need not resemble either of the initial materials. Rather, they may possess unique qualities based on the way that their properties are brought into relation. Texture does not concern hiding digital technologies in physical containers nor does it concern the use of physical objects as representations of information. Instead, texture is fundamentally situated in-between, in a place where we do not ask what is hidden behind what, but instead we look towards how a single composition is crafted from physical and digital materials. Texture is a term that makes no ontological distinction between the digital and the real.

Texture is a term well-suited to exchange with new communities that will become increasingly central to design.
discussions as we cross the physical-digital divide. Increasing not only the range of materials within interaction design but also our repertoire for creating relations between these materials promises to generate new connections between interaction design, architecture, interior design, landscaping, art, and materials science. Texture is but one concept that might function across these fields.

Conversely, by explicitly focusing on material properties we might be pushed to think about what can’t be done with tangible computing. Exploring the limits of tangibility not only helps define the area, it provokes questions about the tensions between embodiment and imagination, and prompts new strategies for re-focusing instead on this division, rather than one between the physical and digital.

Texture generates theorization of similarly under-explored concepts like materials, elements scale, datum, rhythm, transformation, circulation, approach and entrance [7]. Proposing terms that support a material turn could lead not only to the creation of new materials and environments but might also lead to development and evaluation of new terms, concepts, and frameworks that will, in turn, generate new research questions and open new spaces for design. If we are to truly follow the material turn we can no longer rely on concepts like “blending of the physical and the digital” which will carry a physical-digital divide history with it. Instead, as we approach areas like art, architecture, and urban design we need a vocabulary that enables an address of the digital as though part of everyday life.

Figure 5. Opening day at Icehotel X.

Texture shifts the focus of interaction design away from façades and surfaces and towards potential intersections with architecture and material sciences. Hopefully, the result will be to look upon old materials with new eyes. As with water displays, where, computational control renders images in dripping water, new textures will emerge based on material properties like flow and gravity that were always already there. A complex solution for representing information could be done thus at the same time expanding our thinking about application areas of water as a material through a texturized understanding of this material as something like “computational water”.

Approaching computational power from the perspective of texture encourages designed to achieve particular effects by considering potential material properties desirable for interaction. From this vantage no interface or computer need be integrated into the environment. Rather, the environment would be composed of relations between materials, or textures, that might have new kinds of names. This kind of sensibility, already present in architecture and industrial design, might find its way into the working vocabulary of interaction designers.

As a field of research focused on the exploration of new materials and interaction with and through these as put together in new compositions we should also acknowledge not only the product of inventing these materials, but also to document how we produce these new textures for interaction. From our perspective this is a design research area waiting to be articulated which could inform e.g. the creation of catalogues of computing textures. At the same time, a close-up focus on the process could also enable a rethinking for what computational power is about, potentially provoking cultural debates about what computing essentially is.

By regarding texture as a property applicable to the computational we can refine our aesthetic distinctions around new kinds of textures for ranges of material organizations for computing. Not only desktop computing but also peer-to-peer networking, cloud, and grid computing, might contribute unique aesthetics that can be designed for and revealed in exiting ways.

Finally, seeing the material properties already at our disposal, the texture of the world can help guide sustainable design. Perhaps the properties we seek in the computational are often already part of the everyday material world. Organizing design in terms of these properties might help us understand when we need to invent something new, and when a mundane ubiquitous substance as simple as water, provides exactly what we need.

ACKNOWLEDGEMENTS

The research reported in this paper was partly financed by the EU (Objective 2)- project “xID 2.0 – Interaction Design in Extreme Environments”. We would also like to thank the Kempe Foundation for funding time for the writing of this research. The authors have contributed equally to the writing of this paper, and are listed in alphabetical order only. We thank our reviewers for their valuable comments, and a big thanks goes to our project partners including: ICEHOTEL, Philips and Jung von Matt.

REFERENCES


