Smart Material Interfaces: A Vision

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Abstract. In this paper, we introduce a vision called Smart Material Interfaces (SMIs), which takes advantage of the latest generation of engineered materials that has a special property defined "smart". They are capable of changing their physical properties, such as shape, size and color, and can be controlled by using certain stimuli (light, potential difference, temperature and so on). We describe SMIs in relation to Tangible User Interfaces (TUIs) to convey the usefulness and a better understanding of SMIs.

Keywords: Tangible User Interfaces, Ubiquitous Computing, Smart Material Interfaces.

1 Introduction

Although the tangible representation allows the physical embodiment to be directly coupled to digital information, it has limited ability to represent change in many material or physical properties. Unlike malleable pixels on the computer screen, it is very hard to change a physical object in its form, position, or properties (e.g. color, size) in real time.

– Hiroshi Ishii [5]

Mark Weiser's [18] vision of Ubiquitous Computing motivated researchers to augment everyday objects and environments with computing capabilities to provide reality-based [7] and more natural interaction possibilities. One of the most promising sub visions has been the tangible user interfaces (TUIs) [6]. In TUIs it is proposed to use physical handles to manipulate digital information. Some of the known examples of TUIs are Urp [16], actuated workbench [11], Illuminating Light [15], MediaBlocks [14], Siftables [8] and SandScape [4]. One of the major limitations of TUIs is that they focus more on the input mechanism and less on the output. As Ishii [5] explained, the incapability of making changes in the physical and material properties of output modalities is a major limitation of TUIs. Building on this limitation of TUIs [5], we propose a sub vision entitled Smart Material Interfaces (SMIs). The main focus of a SMI is being able to make changes in the physical and material properties of output modalities. SMI proposes the use of materials that have inherent or "self augmented" capabilities of changing physical properties such as color, shape and texture, under the

A. Camurri, C. Costa, and G. Volpe (Eds.): INTETAIN 2011, LNICST 78, pp. 57–62, 2012.

control of some external stimulus such as electricity, magnetism, light, pressure and temperature.

The purpose of this paper is to draw attention to this upcoming field of research. In this paper, we describe SMIs in relation to TUIs to convey the usefulness and a better understanding of SMIs. We first describe our motivation behind this work. Next, we describe the vision of SMI with reference to TUIs. In the end we provide future directions for SMIs.

1.1 Motivation

There are three main motivations for introducing such a vision, in the ever growing field of ubiquitous computing.

First, we believe that there is a need to make the vision of ubicomp, as conceived by Mark Weiser [18], more relevant. We see a trade-off in the ways this vision is applied in the current research. The central idea behind the vision of ubicomp is to seamlessly embed computing in the everyday used objects, both socially and procedurally. The material qualities of these everyday objects play a big role in the social and procedural practices of people. In the current ubicomp research, the material and the computation are seen detached from each other [17]. As Buechley and Coelho [2] suggest, electronic components are seldom integrated into objects' intrinsic structure or form. We believe that there is a need to highlight the blurring boundaries between the material qualities of an object and the computational functionalities it is supposed to support.

Second, the technology push from different fields of material sciences has provided new possibilities to integrate materials such as metals, ceramics, polymeric and biomaterials and other composite materials for designing products. A wide range of smart materials can be seen in the literature that can change their shape, size, color and other properties based on external stimuli. These properties of smart materials can be used to create new kind of interaction and interfaces. In section 2.1, we will provide a few examples of these materials.

Third, with the use of smart materials, as designers, we can introduce a new communication 'language' to users. Use of screen-based interfaces has dominated the user interfaces for several years now. These use icons, texts, and other types of widgets to support communication with users. Smart materials can introduce new semantics to the human-computer interaction, which focuses on change of shapes, colors, size or positioning. Of course, the potential and semantic value of such a type of communication have to be explored and experimented further. However, the use of smart materials can be seen as a radical shift in the way we see our user interfaces.

2 The Vision

The basic idea behind the SMIs vision is that it attempts to sensibly utilizes readily-available, engineered materials as physical properties of an interface to convey information to its users. Additionally, following the ubicomp vision, SMIs attempts to close the gap between the computation and the physical medium

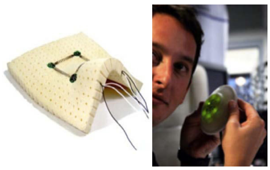
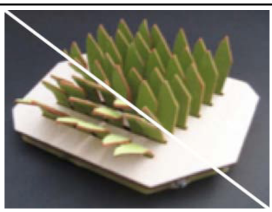
– where the physical medium itself is capable of making changes. Computation and other external stimuli could help in this but it is not a necessity. This way our everyday used objects can convey informations by means of their physical properties and use the material itself as a medium of physical representation. SMIs emphasis on the medium used for the interaction, the object itself, instead of having a simulacrum giving the idea of interaction of another object augmented as input system.

To make the SMIs vision clearer, we will first provide a brief overview of the type of smart materials that are currently available and how they are used in designing interfaces and products. Next, we will provide an informal comparison of SMIs with TUIs – that have been around for some time.

2.1 Smart Materials

Before going further, we would like to explain what we mean by "smart materials". A smart material has at least one or more properties that can be dynamically altered in certain conditions that can be controlled from outside (external stimuli). Each individual type of smart material has specific properties which can be altered, such as shape, volume, color and conductivity. These properties can influence the types of applications the smart material can be used for. The most common smart materials can be in the form of polymers, ceramics, memory metals or hydro gels. These materials are engineered within the fields of

Table 1. Examples of existing smart material interfaces

Concept	Description	Material
	*SpeakCup* is a voice recorder in the form of a soft silicone disk with embedded sensors and actuators, which can acquire different functionalities when physically deformed by a user[3].	Composition of disk of platinum cure silicone rubber (passive shape memory)
	*Sprout I/O* is a textural interface for tactile and visual communication composed of an array of soft and kinetic textile strands, which can sense touch and move to display images and animations.[3]	Shape memory alloy used as electrode for capacitive sensing and actuation soft mechanism.
	Concept that displays different information about safety and risk relative to the temperature of the content of the bottle. Designers: Hung Cheng, Tzu-Yu Huang, Tzu-Wei Wang and Yu-Wei Xiang	Thermochromic liquid crystals

chemistry, polymer sciences and nano technology. Importantly, these fields can offer specific kind of smart material that can be operated using specific external stimuli. For example, polymers can be activated through light, magnetism, thermally or electrically. Other smart materials: NiTinol [10] (memory shape alloy, used for internal surgery); phase change materials [13] (heat is absorbed or released when the material changes state, used for mugs and clothes); chromogenic material [1] (changes color in response to electrical, optical or thermal changes, used in sunglasses and lcd); ferrofluid liquid [12] (becomes strongly magnetized in the presence of a magnetic field, used for Hard Disk and Magnetic resonance).

In the Table 1, we provide some examples of interfaces built using smart materials.

2.2 SMI vs TUI

Figure 1 shows an architectural comparison between SMIs and TUIs and Table 2 summarizes their differences.

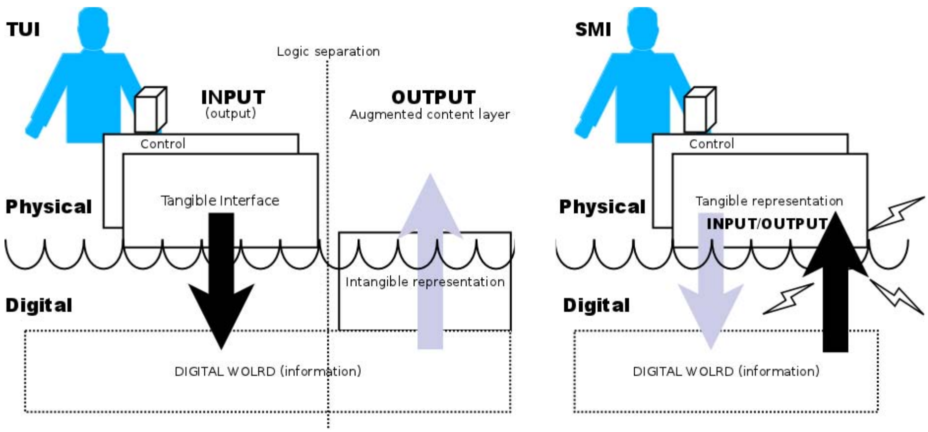


Fig. 1. Making a comparison between TUI (left) and SMI (right), we want to stress the tight coupling of information and tangible interface, and especially the use of tangible elements as output of the system. This will take advantage of the smart properties that can be carried by the object itself as interface. The black arrow emphasize the focus of interest for the interface (as input in TUI, as output in SMI).

TUI. As mentioned in [5], “the tangible representation allows the physical embodiment to be directly coupled to digital information”, but the “limited ability to represent change in many material or physical properties” has been a drawback. As can be seen in figure 1 (left side), the user interacts with a tangible form of information (the object itself) to control the underneath mechanism – the object translates movements into commands and data in a digital form for the system (digital world). Once the computation has been done a different output is prompted to the user. The information returned (augmented content

Table 2. Advantages of *SMI* in comparison with *TUI*

TUI vs SMI	
sometimes incoherent in the relevant ambience (physical - digital)	coherent space of information (physical - physical)
information is represented as an augmented overlay on the object	information is part of the material/object itself
tends to separate input and output (distinction by physical - digital)	promotes a more tight coupling input/output
users can feel the difference from the "real" and augmented information	information added in a completely transparent way
output is felt non-continuous non-persistent	output physically present (not a digital representation), continuous and persistent
balances coupling the tangible and intangible representations	uses physicality of the object as way to deliver information
makes use of electronics and controllers	uses properties of smart materials

layer) can be presented over the tangible interface itself. The user can interact with the augmented layer by moving the physical interface. In TUI, we need to balance the intangible digital information (inside the augmented content layer) and the tangible representation (represented by the object itself) in such a way as to create a perceptual coupling between the physical and digital [5].

SMI. With the use of smart materials, SMI attempts to overcome the limitation of TUI. SMI focuses on changing the physical reality around the user as the output of interaction and/or computation as well as being used as input device. SMI promotes a much tighter coupling between the information layer and the display by using the tangible interface as the control and display at the same time – embedding the augmented information layer directly inside the physical object. It uses the physicality of the object as a way to deliver information. Utilizing smart materials' properties, SMI can support cohesive interaction by maintaining both channels (input and output) on the same object of interaction. The interaction constructed in this way will grant the user a continuous perception of the object and of the output with a persistent physicality coherent with the space.

3 Conclusions: Applications and Future Possibilities

We believe that SMIs could have a wide range of applications, not limited to the field of computing. In fact, literature has shown how smart materials are used in surgery [9], architecture, art and engineering. SMIs do not need any kind of display, with materials being both the interface and input-output stimuli. Their physical characteristics may be enough to carry and convey information. In this way, SMIs propose a radical change in the way we see and understand common user interfaces as well as the way we interact with things, introducing a new space for research and development. We believe that in the future we will have a more seamless interaction between the real world and the digital world. This will provide a new meaning to augmented reality interaction that will have a more continuous, persistent and coherent feedback in relevant contexts.

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