Introduction to the Special Issue on Interaction with Smart Objects

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Smart objects can be smart because of the information and communication technology that is added to human-made artifacts. It is not, however, the technology itself that makes them smart but rather the way in which the technology is integrated, and their smartness surfaces through how people are able to interact with these objects. Hence, the key challenge for making smart objects successful is to design usable and useful interactions with them. We list five features that can contribute to the smartness of an object, and we discuss how smart objects can help resolve the *simplicity-featurism paradox*. We conclude by introducing the three articles in this special issue, which dive into various aspects of smart object interaction: augmenting objects with projection, service-oriented interaction with smart objects via a mobile portal, and an analysis of input-output relations in interaction with tangible smart objects.

Categories and Subject Descriptors: H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms: Design, Human Factors

Additional Key Words and Phrases: Smart objects, interaction

ACM Reference Format:
Schreiber, D., Luyten, K., Mühlhäuser, M., Brdiczka, O., and Hartman, M. 2013. Introduction to the special issue on interaction with smart objects. ACM Trans. Interact. Intell. Syst. 3, 2, Article 6 (July 2013), 4 pages.
DOI: http://dx.doi.org/10.1145/2499474.2499475

1. INTRODUCTION

Computer-augmented, network-enabled objects continue to populate our everyday lives. Vendors and the public often label these objects as "smart products". The term *product* implies aspects that go beyond smart objects in general: For example, the smartness of a product should span several or all phases of its lifecycle (e.g., smart production and maintenance), and its design process should ensure that industrial and economic aspects are systematically reflected. But since these points are not implied by the colloquial use of the term *product*, and since they are not emphasized in this special issue, we will use the terms *product* and *object* interchangeably in the remainder of this introduction.

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DOI: http://dx.doi.org/10.1145/2499474.2499475

We propose the following features that, taken together, determine the level of smartness that is exhibited by a product (in terms of the number of features that an object possesses and the degrees to which it possesses them).

—*Context awareness* is the ability of a product to adapt its behavior to changing situations of use.
—*Proactive behavior* is the ability of a product to look ahead, acting in preparation of potential forthcoming situations.
—*Internalized knowledge* is the internal application of knowledge-based systems, in particular, a reasoning component capable of producing new facts during runtime. While such technology is, in theory, not required for creating more powerful systems than those based on other, more conventional programming paradigms, practical experience shows that they usually exhibit more adaptivity and flexibility.
—*Product-to-product interaction* is the dynamic coupling with peer, embraced, and embracing products. Smartness in this respect is exhibited if collaboration with other products – either at the same level or in a hierarchical setting (smart environments, smart parts) – is supported even if the interaction with the partnering products has not been anticipated entirely. Such behavior can, for example, be supported by knowledge-based technology, such as planning technology.
—*Product-to-user interaction* is a particular form of smartness related to behavior at the product-to-human interface. It is essentially the capacity of *intelligibility* (Bellotti and Edwards 2001), conveying to users what the product knows, how it knows it, and what it is doing.

This set of features provides a reference framework for what constitutes a smart product. In the extreme case, a smart object could adopt all these features, but such an object would raise issues of complexity.

2. THE SIMPLICITY-FEATURISM PARADOX

A key challenge that industry faces when attempting to bring smart objects to market is what may be called the *simplicity-featurism paradox*. Good user experience—which is increasingly recognized as a key selling proposition—calls for intuitive use, which in turn is hard to reach without a reasonable degree of simplicity (cf. Borchers [2008]). Therefore, to bring smart objects to market requires designers and researchers to tame the complexity inherent in these objects. As Norman states in his recent book *Living with Complexity*: "Good design can help tame the complexity, not by making things less complex – for the complexity is required – but by managing the complexity" [Norman 2011, p. 4]. This idea implies that the aim should be not to simplify by design but rather to come up with designs that embrace complexity. Smart objects are not only a challenge but also an opportunity to come up with new design solutions and engineering approaches to ensure they become usable for the end users.

Several academic and research projects have investigated how smart objects can simplify complex tasks. For example, sensors and context awareness in kitchen utensils can help a user to prepare a meal [Lee et al. 2006]. Intelligent technology and algorithms, such as hierarchical task networks and problem solving algorithms, provide a rich foundation for enabling objects to reason about complex tasks and compute on-the-fly plans that can be used to guide the user. For example, within the SmartProducts EU project, a solution combining ontologies, dynamic problem solving, and context-aware workflows [Ständer 2012] was developed and applied to dynamically compute meal plans and guide the user through meal preparation.

But having intelligent algorithms inside smart objects that understand the task at hand is not sufficient for addressing the simplicity-featurism paradox. The system's

understanding must be used as the basis for engaging in meaningful and enjoyable interaction with the user, as indicated in the discussion of the five distinguishing features introduced in the previous section. We believe that, if this strategy is applied successfully, smart objects can become a key technology for resolving the simplicity-featurism paradox and enabling industry to bring ever more feature-laden products to market without paying a price in terms of usage complexity.

3. ARTICLES IN THIS SPECIAL ISSUE

The three articles that appear in this special issue discuss different approaches to enabling effective interaction with smart objects.

In *Cooperative Augmentation of Mobile Smart Objects with Projected Displays,* Molyneaux, Gellersen, and Finney introduce and explore the technique of automatically projecting information onto an object within a ubiquitous computing environment. Their work expands the possibilities for smart objects to externalize their internalized knowledge, since it augments the objects with rich visual output capabilities. In addition, it helps to provide context-aware output, since the method integrates the visual output with the environment and appearance of the physical output. A key element of this approach is the ability to determine the exact pose of smart objects in the scene. The basis for determining the pose is a generic recognition algorithm that is parameterized by a geometric model that is provided by the smart object. Common features of smart objects (e.g., the ability to store digital information and internalize knowledge) are cleverly used to enhance users' interaction with them. The article introduces an ingenious way to combine the image recognition technology with information from sensors on the smart object to improve the pose estimation. The feasibility of the new method is demonstrated by the results of a series of experiments.

Embodying Services into Physical Places: Toward the Design of a Mobile Environment Browser, by Thébault, Decotter, Boussard, and Lu, comes closest to the forms of smart objects that are currently found outside of research labs—not surprisingly, since the authors are affiliated with the research branch of a commercial organization. A service-oriented architecture is introduced that enables smart objects to interact with the user via mobile phone. A key feature of the architecture is its ability to distinguish remote interaction with a smart object (e.g., accessing a smart object such as a smart coffee machine at home while at work) from on-site interaction (e.g., interacting with a smart coffee machine while standing in front of it in the office kitchen). Besides providing an architecture for making products interactive, the proposed approach underlines the importance of context awareness: Users often perceive interaction with objects as "smart" when interaction with these objects is initiated on the basis of the local context. However, the user can override this default behavior of the system by manually and explicitly switching to a remote location. This arrangement illustrates the value of putting the end user in control, an important strategy that calls for well-thought-out product-to-user interaction.

An Analysis of Input-Output Relations in Interaction With Tangible Smart Objects, by van de Garde-Perik, Offermans, van Boerdonk, Lenssen, and van den Hoven, provides an interesting bridge to the field of design research. The type of smart object considered is the *tangible smart object,* a physical object that can be manipulated by the user to achieve particular effects. Focusing on relationships between user input and system output (*IO relations*), the authors distinguish two general patterns of IO relation for smart tangible objects, and they discuss their implications for interaction with such objects. Their research contributes to improving product-to-user interactions but also to creating appropriate designs for complex behavior (cf. the simplicity-featurism paradox). The article includes several case studies that underpin the theoretical framework.

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Received May 2013; revised June 2013; accepted June 2013