Smart Products: An Introduction

Max Mühlhäuser

[1]Technische Universität Darmstadt, Hochschulstr. 10, D-64289 Darmstadt, Germany
max@informatik.tu-darmstadt.de

Abstract. Sophisticated commercial products and product assemblies can greatly benefit from novel IT-based approaches to the conditioning of these products and of ‘product knowledge’, leading to what we call Smart Products. The paper motivates the need for such novel approaches, introduces important relevant challenges and research domains, and provides an early definition of Smart Products.

Keywords: Smart Products, product data, context awareness, human interaction, agent based communication.

1 Introduction and Motivation

This paper presents key statements made at the invited introduction to the AMI ’07 workshop on Smart Products.

The current chapter outlines the need for considerable advancements in the way information, information technology (IT), and products are combined. This is done by taking cars as an example and by comparing past, present, and future issues with respect to two key requirements relevant for (smart) products.

Simplicity: In the past, ease-of-use of cars was “almost built in” (in comparison to the present) in the sense that cars had very limited functionality. Steering wheel, gearshift, and pedals directly exposed the key product features to the user. At present, cars are equipped with a wealth of functionality. Only some of this new functionality can be realized without any need for active user participation (ESP, ABS etc.), the rest cannot operate satisfactorily without means for the user to take influence (air condition, radio, electronoic seat positioning, ...). Almost all these features are accessible via computers[1]. Efforts were made for assuring as little interaction as possible and for greatly improving the usability; further R&D focused on maintaining the user’s feeling of “being in control” in cases were “wheels & levers” expose car functions via computers and not directly any more (cf. power steering, power gears etc.).

As to the future, it has become evident that mastering the “simplicity paradox” will be deterministic for product success: huge efforts towards better usability are foiled by ever more feature laden products, ‘imposed’ by the need to differentiate products from their competitors.

[1] This term is used In the large sense throughout the paper, including microcontrollers etc.

It is important to emphasize that product ‘users’ are by no means limited to the typical customers. Over the lifetime of a product, the quest for a high degree of usability and simplicity equally regards the manufacturing process (cf. shop floor workers), maintenance (cf. repair technicians), and the actual use (cf. different categories of passengers) – and reaches even further, e.g., to the design step in the beginning and resale or recycling at the end. Given the increasing sophistication and ever shorter innovation cycles (which increase the ‘learning’ needs for manufacturing and service workers), simplicity can be identified as a crucial lifecycle-covering need.

Openness: Car production in the past was dominated by the power of the manufacturer. In the early days, everything was ‘produced under one roof’; soon, car manufacturers started to build networks with suppliers, but these networks were initially dominated by the final-product vendor and remained stable over the life time of the model. Today, openness has increased in many ways, in particular the following two: (i) suppliers build trusts aiming at increased independence from car manufactures; on the other hand, manufacturers seek independence from supplier for enabling faster changes in the supply chain, e..g, in case of quality, quantity (production capacity etc.), or price disagreement; (ii) the number and variety of optional parts has dramatically increased, both with respect to the choices at the time of order and with respect to additional equipment introduced during the product lifetime (entertainment systems, mobile phone dockings, special supply parts like racing seats).

In the future, openness will further increase for two major reasons: (i) personalization of cars will remain an important differentiator for vendors and will be driven to even more custom made cars; at the same time, stock production is not a viable option any more if ‘no two cars are identical’ – which is in turn an optimization opportunity since a production process for ‘cooked-to-order’ cars minimizes capital lockup and facilitates the above-mentioned strive for more flexible manufacturer–supplier relations (ii) ever more IT equipment is added to cars after sales and exchanged during the product life time (navigation, phone, entertainment, air condition, etc.). To this end, improved openness helps ‘implanted’ products to leverage off functionality available at the ‘car as a docking station’, like high quality sound systems, speed dependent operations, etc.

But not only will the car be an ‘environment’ in which ‘smaller’ products are embedded: the car itself will become ever more tightly embedded into its environment, as current research on car-to-car and car-to-infrastructure research indicates.

A vast majority of the innovations made in the automobile sector are linked to computers; as a consequence, modern cars contain some seventy computers or more. In this context, it is obvious that advancements in simplicity and openness must be related to computers and information technology, too.

It must be noted that the example of cars used up to now can be replaced by many other examples from the area of *tangible products* (cf. telecommunications, consumer electronics, manufacturing etc.), *software products,* and the *services sector* (both public and private).

2 A Quest for Integrated Research

From the arguments and definitions provided so far, we can derive that a considerable improvement in the **simplicity** and **openness** of products has the potential to facilitate technological and economic advancement[2] – and can thus be considered a key technology for the industrialized and emerging countries. We advocate such an improvement and propose to apply information technology (IT) as the key enabler. On a high level of abstraction, this proposal is grounded on two arguments:

1. IT is *the* overall motor for improved product sophistication; many facets of 'smartness' can be directly linked to areas of IT research and development.
2. The advent of 'ubiquitous computing' (aka pervasive computing, aka ambient intelligence) enables 'real world awareness' in IT solutions: sensors and smart labels (such as RFID tags), wearable and embedded computers connect the statuses, events, and 'constellations' of the real world (here: products and their users and environment) to software in real time without the need for human input. This technological advancement of recent years may be considered a prerequisite for IT-based Smart Products.

Looking at a slightly deeper level of detail, two important major research directions may be identified. They will be related below to pertinent *existing* research domains.

Simplicity: considerably improved product-to-user (p2u) interaction. Information technology must be applied in novel ways for improving the simplicity of interaction between products and their users (of different categories, across the lifecycle, see above). Two major goals must be pursued to this end:

1. The "smartness" of products must be improved, turning them into more adequate interaction peers for humans. With respect to the simplicity paradox i.e. growing number and sophistication of features, improved smartness must help to *hide* irrelevant features (based on improved and dynamically adapted 'knowledge' about which features are actually important and which not) and to *assist* the user with respect to actually relevant features. A number of pertinent approaches were developed in recent years; unfortunately, they were cultivated in different disciplines (AI, HCI, Cognitive Psychology, Software Engineering, Ubiquitous Computing) with different emphasis and published under a variety of headings, such as context awareness, adaptive and proactive user interfaces, adaptive user models, sentient computing, and self-explanation. For an introduction, the reader may consult [6] and [13].
2. The state of the art in mobile multimodal user interfaces must be exploited and advanced. In interacting with products, users will often have to concentrate on attention-demanding primary tasks, be it operation of the product itself (e.g., operating a tool which is about to explain itself to the user as she applies it) or be it a different activity (e.g., driving a car while adjusting the 'air condition Smart Product'). Under such conditions, hands-and-eyes interaction is rarely as adequate any more as it was for desktop PC work. As a consequence, mouth-and-ear (primarily: speech based) interaction has to be cultivated fur-

[2] Further properties are crucial for this success, in particular reliability/robustness and security, but lie beyond the scope of this introduction.

ther. Moreover, available and appropriate interaction modalities and devices must be dynamically federated in order to achieve optimal interaction, cf. [10]; to this end, Smart Products must cooperate with interaction devices available in the environment (cf. p2p interaction below). As to speech based interaction, a lot of emphasis has been put on the core technology i.e. speech recognition and speech synthesis in the past. Since unconstraint natural language human-machine dialog remains far from being at par with human-to-human dialog, the preferable approach taken 'atop' core speech recognition varies. Choices range from 'simple' grammar based approaches (which can reach an astonishing level of usability [11]) via statistical language models and conversational interfaces (cf. [4], [7]) to the use of controlled natural language [12]. Resource constraints of embedded systems (demanding distributed solutions) and environmental noise aggravate the problem space. In light of this, further research as well as agreement about a canonical approach to Smart Product p2u interaction must be regarded as one of the biggest challenges.

Openness: considerably improved product-to-produvct (p2p) interaction. The above-mentioned issue of federated interaction devices indicates that improved p2p interaction (here: device federation) helps to improve Smart Products (here: p2u interaction). More generally speaking, it is fair to say that in a given situation, the actual usefulness and pertinence of a product can only be exploited in the context of its environment. Thereby, 'environment' may refer to three different levels of scope: (i) the encompassing environment (for a car in use: streets, gasoline/parking infrastructure etc.; note the very different environment for a car under construction or a car under repair); (ii) the peer products (in the car example: peer vehicles, traffic lights, toll stations etc.); (iii) dynamically embedded devices (e.g., an mp3 player or GPS receiver brought in by a passenger).

Many publications about smart environments rely *implicitly* on the assumption that such environments be designed to a large degree 'top down' with someone having a holistic view on the overarching purpose of the smart environment, its components, and their interworking. This implicit assumption is debatable for most realistic scenarios in which everyday products are applied, be it in industry or for private use. One can easily show that in reality, the degree of top-down on-purpose design varies considerably (roughly speaking, there is a declining slope, e.g., from production plants to office buildings to private transportation). Support for complementary bottom-up support is beneficial in each case and mandatory for truly open cases like homes and private transport. In other words, smart environments can greatly benefit from a considerable degree of self-organization. Two important areas of research must be considered here again;

1. From the IT perspective, Smart Products can be conceived as 'services'; this way, they can leverage off intensive research on 'service composition' and sub-issues like service (self-)description and discovery, orchestration and choreography. As a basis for vendor independent interworking, intensive research on semantic service composition can be 'tapped' for Smart Products. The most intensive research in these areas concerns Web services and semantic Web services [2]). These emerging service-oriented approaches must be adapted

and extended for use with Smart Products (e.g., by reflecting the concept of active knowledge mentioned below).

2. Beyond service composition as investigated in 'mainstream' (semantic Web) service oriented software research, Smart Products need to exploit more far-reaching self organization approaches. One important research direction in this respect concerns the application of AI planning algorithms for rather descriptive, goal oriented (as opposed to prescriptive i.e. workflow oriented) composition. Extensions of the Semantic Web Services domain in this respect have already been attempted (see [9] for an example). Another important issue concerns the need to automatically identify, distill, and re-use important patterns of product use and of 'product assembly' use. To this end, machine learning and apttern recognition algorithms appear to be promising, especially if context awareness is applied in order to 'feed' machine learning with automatic observations of 'scenes' in which users, products, and their interactions are reliably described (cf. [8] for a patent on an approach to entertainment products). It must be mentioned that self organization (in the sense of self-diagnosis and self-healing) is also an important approach to improved reliability, but as mentioned, this issue is beyond scope here.

P2u and p2p interaction can greatly benefit from an effort to harmonize the modeling and realization of both. In particular, such an effort can lead to a concept for easily exchanging humans by products and vice versa in a given environment. On one hand, one can imagine an ensemble of Smart Products with an entry level of sophistication deployed at affordable cost. As demands (and budget) grow, human involvement may be lowered by introducing additional components (products) which automate formerly manual activities. Therefore, an easy replacement of users by products should be cared for. On the other hand, in case of a defect in one of the Smart Products assembled in a smart environment, manual intervention – for securing overall operation – can be facilitated if a human can easily step in as a replacement for the defective component. Also, repair can be facilitated if humans can mimic the p2p interaction with the defective component itself.

3 Defining Smart Products

A concise definition of Smart Products should be established and widely agreed if a corresponding new research field and community shall emerge. The present paper attempts a first step towards this end.

Definitions for Smart Environments may be taken into account as a first reference, since Smart Products have to be considered in the context of their (typically smart) environment as argued above. Such a definition can be found in [3]: "A Smart Environment is a small world where all kinds of smart devices are continuously working to make inhabitants' lives more comfortable". In [5], the same authors 'redefine' the term as follows: "A Smart Environment is one that is able to acquire and apply knowledge about an environment and to adapt to its inhabitants in order t improve their experience in that environment". It is interesting that the knowledge aspect has obviously been recognized as a key issue – a fact which backs the 'active knowledge' approach to Smart Products taken by the Telecooperation group, see below.

Referring back to the very origins of Smart Environments and Ubiquitous Computing, i.e. to Mark Weiser's ground breaking work, one may remember characteristics that he attributed to future smart environments: "richly and invisibly interwoven with ... sensors, actuators, displays, and computational elements, seamlessly embedded in everyday objects of our lives, connected through a continuous network". In this respect, Smart Products can be viewed as those augmented everyday objects. However, given the considerations from the first two chapters, it is easy to see that the level of sophistication described can only be achieved if smartness is carefully designed-in with products in a product design process, where the actual product and the corresponding smartness are co-constructed; later in the lifecycle, knowledge held by the Smart Product has to consist of both 'constructed' and 'accumulated' parts. Another important finding from the first chapters was the need to cater for different categories of users and environments in the course of the product lifecycle. All these considerations should be reflected in a definition along with the primary aim to improve both p2u and p2p interaction. Altogether, this leads to the following 'early' definition:

> "A Smart Product is an entity (tangible object, software, or service) designed and made for self-organized embedding into different (smart) environments in the course of its lifecycle, providing improved simplicity and openness through improved p2u and p2p interaction by means of context-awareness, semantic self-description, proactive behavior, multimodal natural interfaces, AI planning, and machine learning."

At this point, a short reference shall be made to the specific approach taken at the Telecooperation group. We emphasize the concept of **active knowledge** as a design-center for Smart Products in our research. The term 'active' refers to the ability to autonomously interact with the user. This contrasts the passive nature of most product 'knowledge' that is digitally available to date: one may think of engineering drawings, PLM (product lifecycle management) data, user manuals, and the like. Such passive knowledge is only used today if it 'happens to be' found and accessed by users or processes; moreover, it is bound to a predefined modality. Active knowledge, in contrast, can trigger p2u and p2p interaction based on perceived needs (occurring events, interaction needs 'computed' by the product as part of its smartness, etc.); modalities can be chosen and combined as appropriate. Informally speaking, active knowledge enables p2u interaction where the product "talks, guides, proposes, and understands"; it also enables p2p interaction and thereby the realization of the self-organization properties discussed. At a coarse view, it appears useful to distinguish three classes of Smart Product knowledge:

1. About *itself* i.e. its features and functions, dependencies, product history etc.
2. About its potential and actual *environments*, in particular perceived possibilities to adapt to and cooperate with these environments and their constituents
3. About its *users*, based on elaborate user models that take into account dynamically changing user knowledge (learning/forgetting) and distinguish the different user categories reflected in the lifecycle plus each individual user herself.

This short reference to own work shall be sufficient for the scope of this introductory paper, for a next level of detail the reader may refer to [1].

4 Summary And Conclusion

As an introductory contribution to the AMI workshop on Smart Products, the paper provided a motivation, definition, and quest for integrated research. On one hand, it became evident that quite a number of disciplines and research fields must be integrated towards widespread use of Smart Products. On the other hand, considerable advancements achieved in these fields in recent years give rise to the hope that the integration, adaptation, and furthering of these results can lead to highly sophisticated yet widely useable Smart Products in a not so distant future. This conclusion may encourage interested researchers to develop the area of *Smart Products* into a highly recognized and active new research community.

4 References

1. Aitenbichler, E., Lyardet, F., Austaller,G., Kangasharju, J., Mühlhäuser, M.: Engineering Intuitive and Self-Explanatory Smart Products. Proc. 22nd Annual ACM Symp. Applied Computing. pp. 1632-1637, ACM Press, New York, NY, 2007.
2. Cardoso, J.: Semantic Web Services: Theory, Tools and Applications. IGI Publishers 2007.
3. Cook, D., Das, S.: Smart Environments: Technology, Protocols, & Application. Wiley 2004.
4. Cohen, M., Giangola, J., Balogh, J.: Voice User Interface Design. Addison Wesley 2004.
5. Das., S., Cook, D.: Designing Smart Environments: A Paradigm Based on Learning and Prediction. In: R. Shorey, A. Ananda, M. C. Chan, W.T. Ooi: Mobile, Wireless, and Sensor Networks: Technology, Applications, and Future Directions. Wiley 2006, pp. 337 – 358.
6. Delisle, S., Moulin, B.: User Interfaces and Help Systems: From Helplessness to Intelligent Assistance. Artificial Intelligence Review 18: 117–157, Kluwer 2002.
7. R. Harris: Voice Interaction Design: Crafting the New Conversational Speech Systems. Morgan Kaufmann 2004.
8. Hoffberg, S., Hoffberg-Borghesani, L.: Ergonomic man-machine interface incorporating adaptive pattern recognition; US Patent No. 7136710, 2006.
9. Klusch, M. Renner, K.-U.: Fast Dynamic Re-planning of Composite OWL-S Services. Proc. IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology – Workshops pp. 134-137, 2006.
10. Paternò, F., Giammarino, F.: Authoring interfaces with combined use of graphics and voice for both stationary and mobile devices. Proceedings of the Working Conference on Advanced Visual interfaces AVI '06. ACM, New York, NY, 329-335.
11. Pieraccini, R., Huerta, J.: Where do we Go from Here? Research and Commercial Spoken Dialog Systems. 6th SIGdial Workshop on Discourse and Dialogue, Lisbon 2005
12. Schwitter, R., Tilbrook, M.: Controlled Natural Language meets the Semantic Web. Proc. Australasian Language Technology Workshop 2004, pp. 55-62.
13. Wu, M., Friday, A., Blair, G., et al.: Novel Component Middleware for Building Dependable Sentient Computing Applications. ECOOP04 Workshop on Component-oriented approaches to Context-aware Systems, Oslo, Norway, June 2004.