Editorial

This special issue was prompted by the emergence of a series of research activities seeking to exploit new ICT developments to add *intelligence* to commercial products. In particular, researchers have sought models for binding commercial products with associated information and decision rules which can assist and even guide the way they are handled, used and dismissed. In this editorial we seek to provide some motivation for this set of initiatives by addressing a few key questions.

1. Questions

1.1 What do we mean by intelligent product?

Trying to answer this question may have been the main thrust for launching a special issue on intelligent products. The notion of intelligent product is still rather undecided and we don't currently have a single established model that holds up to all questions. A first question to answer is what we consider to be a *product*. Is it simply an item of commercial value – whether consumable or reusable (asset)? Or is it any "thing" that may have information and some kind of intelligence associated with it, even though the thing does not have any commercial value as such? Can things such as humans, pets, design documents, multimedia files etc. also be intelligent products? From an information architecture point of view, all such things can in principle be handled in similar ways – as long as the information architecture does not impose restrictions on which things can be intelligent products and which ones can't.

1.2 Why seek to create intelligent products?

Manufacturers today are under increased pressure to add value to their product offerings in order to counter the relentless cost pressure applied via low cost production in emerging countries. Two common approaches have been to either seek to add greater value to products by customizing them to better meet customer needs (e.g. automobiles, furniture) or to enhance the way products are used by providing them with associated information offerings (e.g. mobile phones, laser printers). In each case, a specialization of the product occurs – whether it be in terms of different functionalities, different delivery paths, different usage modes – making it increasingly important to maintain information unique to each item in some way. Product individualization also occurs as soon as the product is sold and being used. Even two initially identical product items will have different owners or be used in different conditions. The product usage phase may even begin before it is sold because many products nowadays go through an individual initialization procedure where "normal" operation profiles are recorded and stored. The product's control system can also be fine-tuned so that individual differences in sensor outputs and actuator operations are taken into account, as for engine control in modern cars that continues adapting the control system to changes in the engine during its whole lifetime.

1.3 Why now?

Apart from the societal trends mentioned above, it is clear that developments in ICT have made the notion of gathering, storing and associating information with a particular item increasingly feasible. Information systems developments such as wireless information gathering (RFID, WSNs, RTLS), embedded processing, distributed data management, distributed information search and retrieval mechanisms are nowadays available. Artificial intelligence methods such as reinforcement learning and software agents are increasingly providing mechanisms for enabling the decision making of inanimate objects. Finally, the ubiquity of the internet provides a readily available mechanism for enabling the connection between an object and any information retained about it – be it in one or many locations.

1.4 How far have we got?

The papers in this special issue represent a reasonable cross section of the state of the art in the development of intelligent products. In the commercial area, the advent of technologies such as low cost RFID over the last 5 years has provided a stimulus for automated product identification and tracking in the commercial sector, and has led to a range of models for associating product information with physical goods – whether the information is physically attached to the product (e.g. on a so called *Product Embedded Information Device - PEID*) or held elsewhere on a network. Other work has focused on the challenge of enabling products to make their own decisions - or more realistically to provide support for decisions associated with the product during transportation or usage. This work has begun to explore the practical issues in associating forms of

intelligence with physical products rather than developing a unifying vision for an intelligent product. In the next few paragraphs we outline the contribution made by different authors in this issue.

2. Content presentation

Meyer, Främling and Holmström provide a state-of-the-art survey of earlier work related to intelligent products. The authors propose a new definition of what intelligent products are and how they can be classified according to three main criteria, together with an analysis of why earlier definitions and classifications are not considered to be sufficient. An introduction to enabling technologies is included, grouped into sections on auto-id technologies, distributed information storage and processing, and agent-based platforms. Implementations of intelligent products in real-life applications are presented, which illustrate the impact that intelligent products can have on society, business and individuals. This survey article provides a framework to the reader of this special issue that should allow her or him to situate the other articles of this issue in the landscape of intelligent products.

After the survey article come the paper of Woo, Choi, Kwak, and Kim and the paper of Martínez-Sala, Egea-López, García-Sánchez and García-Haro. Both describe the use of auto-id technology (notably RFID) and distributed systems for tracking and tracing of shipments and products, which are fundamental operations in the domain of supply chain management. The article by Baïna, Panetto and Morel remains in the supply chain management domain but focuses on how to represent product-related information in databases and how intelligent products help to keep the information consistent with the real world. Yang, Moore, Pu and Chong show how intelligent product principles have been applied to product lifecycle management, notably for the maintenance of products that have an embedded controller.

Pannequin, Morel and Thomas show that a product-centric scheduling method can be as efficient as a centralized scheduling method. However, the product-centric method handles disturbances more efficiently than the centralized method. This is a valuable insight because if the product-centric method performs better in the relatively controllable context of a production site, then it can be expected to perform well also in less controllable environments, such as multi-organizational supply chains or similar. Sallez, Berger and Trentesaux also deal with the optimization of routing in production systems using a stigmergic approach, where the intelligent products jointly update the optimal routing by leaving “pheromone traces” that help each other to optimize their joint performance.

Valckenaers, Saint Germain, Verstraete, Van Belle, Van Brussel and Van Brussel propose a separation between what they call the *intelligent being* and *intelligent agent* parts of an intelligent product. The intelligent being is focused on representing information about the product, keeping the information up to date with the real world and providing access to that information. The intelligent agent takes care of all decision-making and action-taking activities based on the information stored by the intelligent being. This separation between intelligent beings and intelligent agents is visible also in the grouping of the articles of this special issue, where the first ones (Woo et al., Martínez-Sala et al., Baïna et al., Yang et al.) are more focused on the intelligent being part while the following ones (Pannequin et al., Sallez et al.) are more focused on the intelligent agent part.

The last paper by Holmström, Kajosaari, Främling and Langius is a position paper that provides an overview of the kinds of real-world applications where intelligent products are used the most for the moment, especially in supply chain management. Based on these applications, the paper proposes an implementation roadmap for organizations that need item-specific tracking, asset management or product lifecycle management. The roadmap shows the implementation steps to take in order to keep the implementation task manageable and avoid making the same mistakes that others have already done before.

3. What next?

In this area, science fiction is way ahead of the research world, with talking cars, humanoid robots and smart vacuum cleaners setting the pace for the intelligent product field. Although many academic and technical challenges remain, perhaps the greatest challenge in this space is in demonstrating that intelligent products are not simply gimmicks but that they have a valuable and useful role to play in a more energy- and material-efficient, cleaner society.

Guest Editors: Kary Främling, Duncan McFarlane