Three Challenges for Future Smart Object Systems

Fahim Kawsar · Fernando Lyardet · Tatsuo Nakajima

Abstract The notion of Ambient Intelligence was introduced to describe a scenario in which, literally, computing is everywhere. This should not be taken in the narrow-minded sense of a computer on every desk, but in the rather subtler one of computers becoming embedded in everyday objects and augmenting them with information processing capabilities. Part of this vision is already becoming a reality, as tagging everyday objects with sensors, actuators and building an instrumented environment are recent practices in industry and academia. In fact, the smart object domain has matured over the years. The combination of Internet and technologies like near field communications, real time localization, sensor networking etc. are bringing smart objects into commercial use. However, there are still many open issues that need to be addressed to bring smart objects out of the living lab prototypes. In this position paper after laying out our understanding of smart objects, we present three research challenges for the proliferation of smart objects that we believe will instigate stimulating discussions in the workshop.

1 Smart Object and Smart Object Systems

The Oxford American Dictionary defines the terms *Smart* as "Having intelligence" and *Object* as "A material thing that can be seen and touched". However, in pervasive computing the term *Smart Object* has been used in several contexts. For example: low cost visual tagged objects have been used in augmented reality environment, RFID tagged objects have been used in supply chain management and other enterprize applications. Typically for these objects, intelligence such as perception, reasoning and decision-making is allocated at the infrastructure where only tracking, identification and sharing are done at the object end. Our previous works on Sentient Artefact [5,3] extend this model by incorporating sensing and perception at the object end while managing reasoning and decision-making at the infrastructure. In more sophisticated cases, intelligence is integrated into the object itself. Examples are Mediacup by Beigl et al. [2], Smart Furniture by Tokuda et al. [9] and Cooperative Artefacts by Strohbach et al. [8]. From a hypothetical point, all these objects can be considered as smart objects if the locality of intelligence is ignored. However, while designing generic smart objects, it is necessary to understand the scope of the so-called "smartness" of objects. Hence, in the rest of this position paper we will consider a smart object as: *"A computationally instrumented tangible object with an established purpose that augments human perception and is aware of its operational situations and capable of providing supplementary services without compromising its original appearance and interaction metaphor. Supplementary services typically include sharing object's situational awareness and state of use; supporting proactive and reactive information delivery, actuation and state transition"*. All the smart objects mentioned earlier can be rationalized under this annotation. For example: the smartness of a tagged object can be seen in the delivery of its identity information; Mediacup's [2] and Cooperative Artefacts' [8] smartness can be contemplated in sharing situational awareness; AwareMirror's [3] smartness can be observed by its proactive information delegation, etc.

1.1 Smart Object Systems

In general, smart objects operate individually, or are collectively integrated by proactive applications or collaborate

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with peers to attain a specific purpose. When working collectively a network of smart objects is formed which is often referred to as a smart object system[1]. Henceforth, we observe smart objects systems from three perspectives:

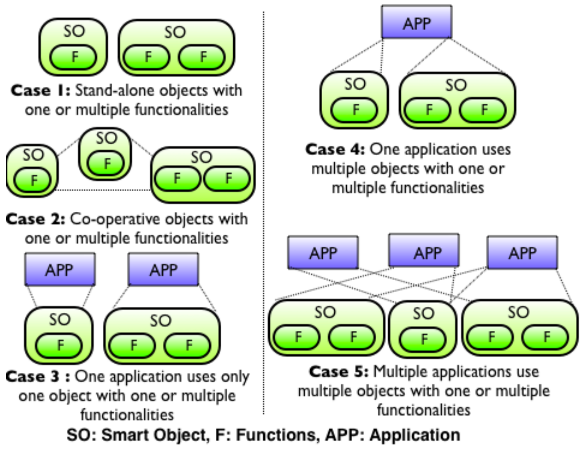

Fig. 1 Different use cases for smart object systems

1. Standalone and self contained objects that are independent of any infrastructure and are capable of perception, reasoning and decision making autonomously with appropriate perceptual (auditory or visual) feedback (case 1 in Figure 1). Examples are Mediacup [2], commercial smart objects from Ambient Device [1], etc.
2. Applications integrating multiple smart objects, specifying the interactions between smart objects in order to provide some proactive services(case 3-5 in Figure 1). This application is executed by another entity who orchestrates the smart objects. Typically a back end infrastructure is utilized by the application for the integration of smart objects. Examples include a smart space with multiple smart objects [4], ambient gaming [6], etc.
3. The third perspective lies in between, stand-alone smart objects are also capable of communicating with peers for taking autonomous actions thus creating a co-operative ecology of smart objects (case 2 in Figure 1). Cooperative artefacts [8] is an example of such an initiative.

2 Three Challenges for Future Smart Object Systems

Historically, the evolution of computing in the last few decades could be seen as the prime indicator for laying out the future research challenges for smart object systems. In the early 80's when the personal computer was first introduced, it was a stand-alone device with a few bundled software. Those machines offered little extension support and very few third party applications were available for them. However, with the advent of general purpose operating systems, the explosion of the internet and the proliferation of low cost hardwares, more companies are now involved in developing innovative softwares and manufacturing personal computers and peripheral accessories. The end users' role has also changed in parallel. Now average computer users can buy a software or download an application from the internet and install it in their personal computers easily. Furthermore, they can attach peripherals (e.g., a video camera, a microphone, etc.) seamlessly to get the fullest functionalities from their desired applications. We are seeing the same phenomenon in mobile computing too. In the early 90's when the mobile phone was introduced, it was a mere cordless phone. However, as the network infrastructures improved and market become saturated, mobile phones have undergone a metamorphosis. It has become a fashion accessory, a mobile office, a music player, a camera, etc. With the release of the development toolkit such as the iPhone SDK we have seen thousands of innovative third party applications for the mobile phone. Most importantly the end users are actually involved in transferring their mobile phone into a multipurpose device: they can now download and install their desired applications with a single touch and can extend the basic functionalities of their mobile phones. We argue that to bring smart objects out of the laboratory, it has to go through the same metamorphosis as personal computer and mobile phone . Specifically, we outline here three challenges that need to be conformed for the proliferation of smart object systems.

1. **Decoupling Smart Features from Smart Objects and Designing Extensible Smart Objects:** Current practices typically augment a physical object with a specific scenario in mind. As a result the capability and augmentation are tightly coupled with the application scenario limiting reusability of the smart objects. However, it is hard to confine a single augmentation for a physical object and multiple objects could provide the same functionalities with different granularities. Consider Figure 2, depicting two ideal situations, a) a single everyday artefact capable of playing multiple functional roles and b) multiple artefacts sharing an identical functional role. In Figure 2(a) we have a smart table providing two supplementary functions: an ambient display and a proximity detector. In Figure 2(b) we have a mirror whose display functionality can be triggered by any of the three augmented artefacts, e.g., a toothbrush, a comb or a razor. The suitable augmentation of these artefacts depends on the underpinned scenario, regardless of the multiple functionalities that can be afforded. Thus smart object should be designed in a generic manner such that the smart features are independent of the physical object. It should be possible to apply the same feature in multiple physical objects. Furthermore, these smart objects should be extensible, i.e., we should be able to gradu-

[1] Often the terms "smart object" and "smart object system" are used interchangeably.

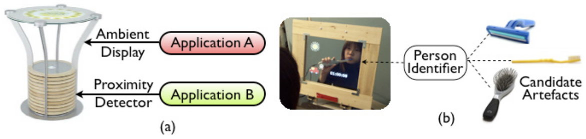

Fig. 2 A single artefact with multiple roles and multiple artefacts with similar roles

ally add advanced features into existing smart objects just like the way we attach add-ons to personal computers. One possible design approach is to have a core runtime available at every smart object with a plug-in architecture that allows independent smart features to be plugged into the core.

2. **Developing General Purpose Applications Independent of Smart Objects:** The evolution of personal and mobile computing clearly shows the role of 3rd party applications. It is necessary to build applications for smart objects in a generic way so that the same application could run on multiple smart objects and one smart object could host multiple applications. Consider, a smart mirror augmented with a display. One application could turn this mirror into a personalized information (e.g., news, weather forecast etc.) display and another application could make it an ambient feedback of household energy consumption through persuasive art in an attempt to make inhabitants more energy conscious. Both the applications could utilize the sensors mounted on the mirror to understand the context of the users and to trigger its display functionality appropriately. The basic argument here is that, by allowing smart objects to host any suitable application, we are opening new opportunities for the designers and application developers to re-innovate the role of everyday objects.
3. **Involving End Users in the Deployment, Configuration and Maintenance Processes:** Till date most of the smart object prototypes we have seen are mainly research initiative. As the technology is becoming mature and reaching end users, it is essential to build smart objects systems in a more human-centric way, i.e., we need to understand how we can involve end users in the administration of smart object systems. Most of the user-centric research on smart objects looked at the interaction paradigms. However, it is also essential to understand how to place and manage smart object systems into the environment. This is particularly important for the home where the dwellers have a greater control. Previous studies have shown how end users continuously reconfigure their homes and technologies within it to meet their demands [7]. To support the evolutionary nature of our homes it is essential that smart object systems support the incremental deployment, configuration and management. Ideally,these activities should be carried out by the end users. The end users have in-depth knowledge of the structure of their home and their activities, resulting in a better understanding of where and which physical artefact and application to deploy. Furthermore, involving end users in the process leads to higher acceptability and a greater feeling of having control due to their active participations. It also reduces deployment, configuration and management costs as professional assistance is not needed. Most importantly, it is important to consider the existing mental models of end users towards everyday object and information appliances. As a smart object designers, we must need to adhere this mental model while offering new affordances from these everyday objects. Considering these factors, we argue that it is very important to design smart object systems in a way that involves end users actively in deployment, configuration and maintenance processes.

3 Conclusion

Smart object research is approaching towards a convergence stage. Many prototypes and constituent sensors/actuators are built and demonstrated. However, there exist a missing link among these research endeavors that limit the reusability and interoperability of these objects design and functionalities. In this position paper, we laid out three research challenges for future smart object systems based on our experiences. We hope these challenges are inline with workshops goal and will instigate stimulating discussions.

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