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Three Challenges for Future Smart Object Systems

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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. 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 [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 [2,7]. Eventually, if the locality of intelligence is ignored, all these objects can be considered as smart objects. In this 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 significantly. Supplementary services typically include sharing object's situational awareness and state of use; supporting proactive and reactive information delivery, actuation and adaptive state transition"*.

1.1 Smart Object Systems

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

1. **Stand-alone Smart Objects:** These are self contained smart objects independent of any infrastructure and are capable of perception, reasoning and decision making autonomously as shown in the category 1 of the Figure 1. The awareness technology along with contecxt-aware services are typically embedded into the object per se. Examples are Mediacup [2], Ambient Device [1], etc.
2. **Co-operative Smart Objects:** Smart objects that are capable of communicating with peers to share their self

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

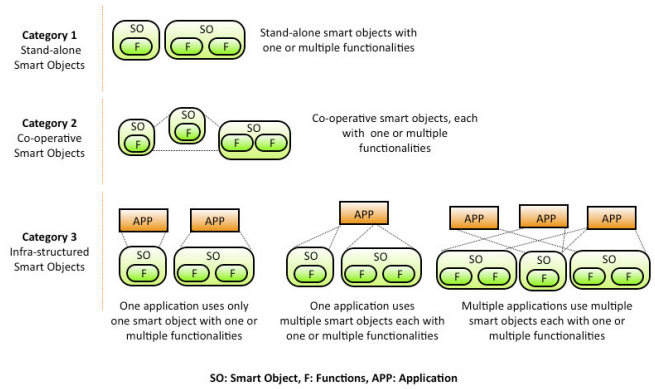

Fig. 1 Different Categories of Smart Objects Systems

awareness for taking autonomous actions collectively thus creating a co-operative ecology of smart objects. A secondary infrastructure often are used in these types of systems. This is shown as category 2 in the Figure 1. Cooperative artefacts [7] in the industrial work place is an example of this class of smart objects.

3. **Infra-structured Smart Objects:** These smart objects are constituents of a larger system. Typically, one or multiple context-aware applications integrate these objects (both stand-alone and co-operative smart objects) into a proactive system utilizing a secondary infrastructure. There could be different use cases for infra-structured smart objects as shown in the category 3 of the Figure 1. Examples include a smart space with multiple smart objects [4], ambient gaming [6], etc.

2 Three Challenges for Future Smart Object Systems

We argue that to bring smart objects out of the laboratory, we must apply the lessons learned from the evolution of the personal computer and the 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:** 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. We claim that smart objects 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 gradually 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. However, it is hard to confine a single augmentation for a physical object and multiple objects could provide the same functionalities with different granularity.
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. 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. 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.

3 Conclusion

Smart object research is approaching towards a convergence stage. However, there exist a missing link among these research endeavors that limit the reusability and interoperability of these objects design and functionalities. To bridge this gap, we laid out three research challenges for future smart object systems based on our experiences that we believe will be beneficial for future smart object system designers.

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