Cognitive Objects for Human-Computer Interaction and Human-Robot Interaction

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ABSTRACT

We introduce and define Cognitive Objects for human-robot interaction and human-computer interaction and disambiguate them against existing 'Smart Objects'. Cognitive Objects are physical real-world objects used in manipulation tasks by humans and robots. As such, they incorporate self-awareness, reduce ambiguity and uncertainty in object recognition, and provide services to both humans and robots during their usage in real-world environments.

We distinguish Cognitive Objects from other 'Smart Objects' and computationally enriched artifacts, outline their characteristics, and describe their potential impact on human-computer and human-robot interaction with real-world objects.

Categories and Subject Descriptors

H.1.2 [**Information Systems**]: User/Machine Systems—*perception, cognition*; I.2.9 [**Artificial Intelligence**]: Robotics—*sensors, manipulators, autonomous*

General Terms

Design, Experimentation, Human Factors, Theory

Keywords

Robotics, Sensors, Actuators, Human-Computer Interaction, Human-Robot Interaction, Ubiquitous Computing

1. INTRODUCING COGNITIVE OBJECTS

1.1 Motivation

With the dawn of personal robotics, we see the advent of physical spaces jointly inhabited by humans, robots and all physical-digital artifacts especially in Ambient Assisted Living or Ubiquitous Computing scenarios. These environments are characterized by their complex, dynamic and frequently changing configurations between objects, systems, humans and robots. Most tasks and interactions involve the manipulation of real world objects – such as serving a cup of coffee or setting a dinner table for two. In such real world environments, the reliable and accurate perception and recognition of objects is still far from being perfect, e.g. due to changing light conditions, occlusions, or in general sensor noise. The computational complexity of recognition, perception and planning processes is limited by the requirement to react and interact in (near) real-time e.g. in human-robot interactions. Additionally, novel sensors, such as 3D depth sensors as the MS Kinect, still impose significant load for processing or on the communication channels, e.g. in a robotic system or with the environment. Consequently, approaches for reducing the required processing power, e.g. by reducing the ambiguity in sensor data or by supporting object recognition processes, are highly desirable. Furthermore, not all parameters intrinsic to an object are externally observable. This e.g. includes physical properties like the temperature of the contents of a coffee mug or the the center of mass that influences how an object affords [8] to be picked up, but also virtual/digital properties such as the usage history of an object or its purpose [9].

With the introduction of Cognitive Objects (CO) in the manipulation task we provide in-situ support for human-object and robot-object interaction. We provide a clear definition of our notion of CO, distinguish and disambiguate them from other 'Smart Objects' research and situate our approach in the body of literature of human-robot and human-computer interaction.

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1.2 Definition of Cognitive Objects

We define Cognitive Objects as *physical artifacts embodied in an interaction which include sensors, actuators, communication and computation, to equally support humans and robotic systems in the task execution.* This definition entails the following aspects that distinguish Cognitive Objects from other 'Smart Objects':

Physicality: CO are no agents or digital representations, but physical objects incorporating affordances for humans and robots. They have an identity (each object is unique) even if mass produced.

Embodiment: CO are embodied both in the task or action they are involved in and the environment. This is possible by holding semantical knowledge about themselves (such as the purpose of an object, how and when to use it, usage history, etc.), supporting the concept of *situatedness.*

Sensing: CO are able to sense external (e.g. for joint perception) and internal parameters (otherwise hard or impossible to perceive). They reduce ambiguity in sensor data by actively cooperating in robot-object interaction.

Actuation: CO can react in interaction processes, e.g. on humans by providing services and robots (e.g. by IR LEDs).

Communication: CO include the properties of Wireless Sensor Nodes (WSNs), constituting an energy-efficient means of communication, but discriminate from WSNs in that all CO are unique (unlike N WSNs of one type).

Collaboration: CO collaborate with humans, robots and the environment – proactively and situated. They reduce necessary a-priori knowledge to use and interact with an object, as this knowledge is distributed and directly provided by the respective object. Strengths of humans and machines (e.g. robots) are individually supported.

CO are situated in the body of related research on WSNs, robotics, and human-computer interaction (HCI).

1.3 Distinction from Related Work

Technology-augmented real-world objects have been discussed in different forms. Embedded RFID/NFC tags make objects uniquely identifiable [3], and the location can, in very limited ranges, be estimated using RF signal presence and strength. While identification allows, e.g. via hyperlinking, to add further data, this usually does not include e.g. information about the purpose of an object or its usage.

Artifacts augmented with sensing, computation and optionally communication are known as so-called 'Smart Objects'. Enabling technologies include [7]: computing power, memory, connectivity, sensors, actuators and displays. Examples are the 'MediaCup' [1], industrial 'Cooperative Artifacts' [11] or tangible user interfaces [12]. 'Smart Objects' use digital technology for additional functionality, focusing though only on improving individual interaction with the object or with the environment. They are not necessarily cooperative (i.e. interacting with other objects, humans, robots or the environment), do not afford usage by humans *and* robots, and do not necessarily incorporate communication abilities at all.

Interactive spaces, so-called intelligent environments, emerge due to the availability of embedded computing technology, e.g. from the research on Ubiquitous Computing [13]. They are the basis for future health care systems [6], or service scenarios involving rooms and buildings augmented with sensors and actuators, e.g. for context-aware systems or location-based services. The focus of these objects is on novel, interactive services for human users or for the inference of contexts such as activity, usage, or presence. Wireless sensor network platforms used in that context, such as Motes [2], consist of a standardized platform able to energy-efficiently communicate reliably wirelessly with other devices in their vicinity or the environment dynamically, collect data and perform signal processing. In contrast to Cognitive Objects, the nodes here are usually all identical in terms of hardware and software and differ only e.g. in the used sensor boards (which are usually again identical for different scenarios). Examples from the area of intelligent environments are SmartIts [4] that were customized by specially designed add-on boards. However, these augmentations are not intended for direct human interaction. The nodes are therefore often placed unobtrusively or hidden of human view in order not to obstruct the room appearance.

2. CONCLUSION AND FUTURE WORK

In this paper, we defined Cognitive Objects and listed their characteristics and requirements to support interaction between robots and humans that existing Smart Objects so far do not entirely fulfill.

We plan to support embedded interaction [5] with Cognitive Objects in our intelligent environment we created as live-in lab [10] and hope to foster research by our contribution of a clear distinction for intelligent artifacts equally supporting and usable by humans and robots.

3. ACKNOWLEDGMENTS

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