How to design adaptive recommender smart objects in EUD context

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Abstract

In a previous work we introduced a classification of types of intelligence in smart physical objects, discussing how they can be taken into account when designing an object. In a later one we focused on a specific task – interactive adaptive support and recommendation to people — and we analyzed in detail the design of smart objects performing this task. The result of this analysis is a conceptual model which is specifically suited to design smart objects performing adaptive recommendation. The model we proposed is centered around the idea that intelligence is multi-faceted and involves different aspects, ranging from interaction abilities to the ability of managing knowledge and of reasoning and learning from experience. In this paper we aim at adapting this latter model to a End-User Development (EUD) context in order to be able to provide adaptive recommendation to the End-User.

Keywords

smart objects, recommender, EUD

1. Introduction

A smart interactive space is an ecosystem of agents featuring cross-interactions whose activation supports the accomplishment of some activities. Besides the user interacting within the smart space, the involved agents can refer to different classes of smart resources. The basic resources are IoT devices, i.e., digital equipment consisting in a variety of things – such as Radio-Frequency IDentification (RFID), tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to communicate, i.e., interact and cooperate with their neighbours in a network, to reach common goals. IoT devices are the basic components of smart objects, i.e., physical objects, computationally augmented with IoT devices, that have the capabilities of sensing and collecting information about their use or about the surrounding environment, to process or transmit this information and finally enact some actions upon their users or the surrounding environment, based on the collected information or an external command [1] . The design of smart objects attracted a lot of attention over the last decade and a number of examples are available in the literature [1, 2] and on the market. In a previous paper [3] we introduced a classification of types of intelligence in smart physical objects, discussing how they can be taken into account when designing an object. In a later one [4] we focused on a specific task – interactive adaptive support and recommendation to people — and we analyzed in detail the design of smart objects performing this task. The result of this analysis is a conceptual

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model which is specifically suited to design smart objects performing adaptive recommendation. The model we proposed is centered around the idea that intelligence is multi-faceted and involves different aspects, ranging from interaction abilities to the ability of managing knowledge and of reasoning and learning from experience. All these dimensions assume peculiar features when attached to a physical object and this is the principle guiding our analysis which borrows and integrates concepts from different areas of artificial intelligence, cognitive sciences and human-computer interaction. The model is organized in a number of layers (or steps). Isolating layers can in our view facilitate the design process and the mapping between requirements and choices in the object to be designed.

In this paper we aim at adapting this latter model, namely ARSPO (see below), to a End-User Development (EUD) environment in order to be able to provide adaptive recommendation to the End-User, in the context of the Empathy project[1]

2. Definition

An **SPO** is a **Smart Physical Object** with interacting and problem-solving capabilities, defined as the tight and seamless integration of a physical and a digital counterpart which augment each other into a unique peculiar entity. This remark is important in characterizing "intelligence" in the sense that intelligence cannot be independent of the physical nature of the object and must augment this physical dimension in the same way as the physical dimension is the handle to support intelligent behavior enabled by the digital dimension. Although a smart object can be seen as an "Intelligent Agent" according to classical definitions [5], it is different from a mere software agent since it has a body and this may impact on cognition and behavior. **ARSPO**: **Adaptive Recommender SPO** are systems that support a user in her activity or decision-making process by suggesting items (services or information) which are supposed to be relevant to her [6, 7, 8]. Recommender systems may take into account the user/s preferences and features, stored in a user profile or – *User Model* [9, 10, 11] – and may also take into account the specific context in which the user and the object interact, including aspects such as the place, the time, the weather, the presence of other objects [12]. This includes the notion of context and situation awareness [13, 14], commonly used in the literature. We use the term ARSPO to refer to an SPO which takes into account all of these features when interacting with a user.

3. An overview of layers in ARSPO design

Once the high level decisions are made and thus the requirements are available, the design of an ARSPO can be decomposed into five layers, as shown in Figure 1.

INTERACTION LAYER. Requirements and design decisions concern the integration between the physical and digital dimensions of the object and thus the interfaces it can offer to users. In [3] the type of interactions between humans and artifacts are defined at the following levels:

- *Task level* refers to the functionalities an object provides and the tasks reachable using such functions;
- *Syntactic level* identifies the modes to interact with an ARSPO, considering both physical and digital properties;
- *Semantic level* refers to the meaning associated to the interaction with an ARSPO;

[1] http://www.empathy-project.eu/

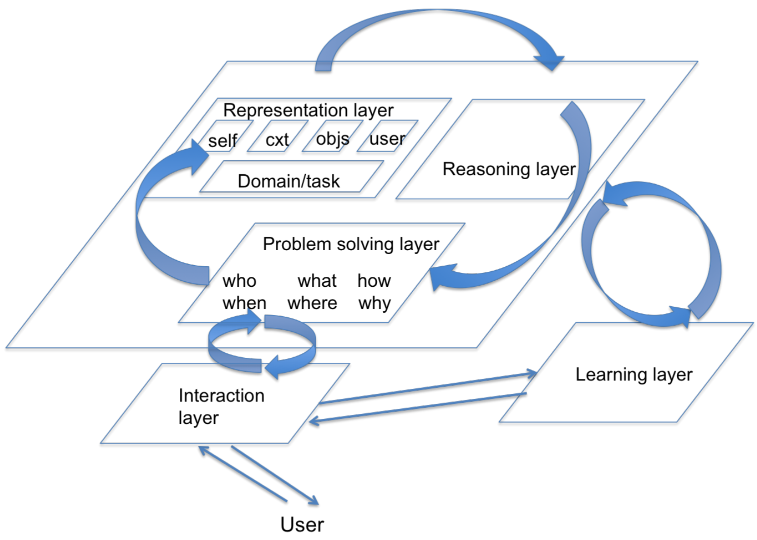

Figure 1: Schema of the layers

- *Interaction level* constitutes the dialogue and relationships between a user, an artifact and the environment. It represents the highest level of interaction, based on complex forms of influence between people and objects.

REPRESENTATION LAYER. Requirements and design decisions regard the type of information that the object should manage. At an abstract level they can be divided in knowledge about: (i) itself, (ii) context, (iii) other smart objects, (iv) user, (v) domain, including the services the ARSPO can offer, the interaction modes it can choose and the criteria for making these choices. (I) Methodological instruments to manage the representation layer concern at least two issues:
- *level of conceptualization* (i.e., representation of the features and properties of the users, other objects, items to be recommended, the environment, etc.). The design choices range from no conceptualization at all (with features and properties represented only as labels or names) to a full conceptualization with ontologies [15], with a full spectrum of intermediate situations.
- *ontological categories to model knowledge*: a useful model can be borrowed from model-based reasoning [16]. It describes four types of knowledge [17]:

- *Teleology* (the goal(s) an object is designed to have),
- *Function* (the functions the object can perform to reach its goal(s), "what the object can do"),
- *Behaviour* (the way a specific function is executed, i.e., the actions that the object performs when a function is activated, "how to do"),
- *Structure* (the physical/digital structure of the object).

REASONING LAYER Requirements and design decision concern the ARSPO's ability to make inferences on information available from the context, the user, other objects, exploiting knowledge in the representation layer. (I) Different forms of reasoning can be classified schematically by referring to a limited set of reasoning patterns commonly used in AI applications [18]: (i) *deductive*, (ii) *abductive*, (iii) *inductive*, (iv) *analogical*, (v) *common sense*. Deduction concerns inferences that extend factual information using the principle of logical consequence. Abduction allows explaining observations using the available knowledge and is a form of non monotonic reasoning.

PROBLEM SOLVING LAYER. (R) Requirements and design decision concern the strategies to provide adaptive recommendation, i.e., "what" services should be offered, "how", "where" and "when", given the individual user ("who") and context. This is the core layer of an ARSPO. This layer shares the reasoning techniques described in the above layer, but focuses on the dimension of the services to be offered, the interaction modes and the mappings to select them.

LEARNING LAYER Requirements and design decision regard the ARSPO's ability to learn from the interaction with the user, possibly after feedback on the recommendation process. The ability to learn has been often considered a fundamental ingredient of intelligence [18]. Learning is a reasoning activity and thus concerns the reasoning techniques discussed above. However, learning is peculiar in the sense that not only does it exploit a knowledge base but it builds/refines/revises it as well. This is the reason why it is kept separate from the reasoning layer.

4. A proposal for designing adaptive recommender smart objects in EUD

In this new wider concepts it is necessary to define all the actors that are:

- The **final user**, which is the recipient of the environment;
- The **end-user**, which is in charge of configuring the environment, and is the one receiving the recommendations;
- The **environment**, e.g., type, goal;
- The **smart objects**, namely all the objects in the environment that interact with the user or with other objects. As far as smart objects are concerned, we have to consider the kind of required input, the type of output, how they communicate with the user, how they communicate with other objects / environment, where they have intelligence, etc.

In the following Figure (see Fig. 2), we present the model adapted to EUD context, describing each "connected" object of the environment. With respect to the original model, we transformed the semantic level in the list of ontologies that can be used to represent the layer. Moreover, for each "connected" object of the environment, we focus on what is important under a interaction and recommendation perspective namely the following layers: *Input layer, Output layer, Interaction layer - user to object, Interaction layer - object to object, Representation layer, Reasoning layer.*

The reader should notice that, in Figure 2, we report, as running example, a smart chair in a smart house used by an elderly user and programmable by her son, which could hypothetically decide the tasks and the interaction model with the user and other objects in the house, etc.

5. Conclusion and Future Work

In the context of the Empathy project we are carrying on a classification of smart objects in use, according to the above actors and layers, in order to evaluate the completeness of our model. We will revise and update the model accordingly with the aim of defining the conceptual model for the end-user recommendation system in the project's smart environments.

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		EXAMPLE OF OBJECT: SMART CHAIR	ONTOLOGY (possible reference ontology)
INTERACTION LAYER **User - Object**	**Task level** refers to the functionalities an object provides; (WHAT)	**OUTPUT** : The chair can: - Raise or lower the backrest - Warm up - Vibrate **INPUT** : The chair needs to know from the user which function to activate	Smart Applications REFerence (SAREF) Ontology, to describe devices and their functions.
	Syntactic level identifies the modes to interact with an object. it can be based on complex forms of interaction (vocal, gesture, etc (HOW)	The user can give instructions through: - GUI on app - Text - Vocal - Gestures	---
INTERACTION LAYER **Object to Object**	**Task level** refers to the functionalities an object provides;	**OUTPUT** : The chair can give information to other objects (for example intelligent scale) of: - How much user was seated in one day - Posture **INPUT** : The chair needs to know from other objects (smart thermometer): - the temperature of the house	**Hydra, CoRAL**
REPRESENTATION LAYER[1] **What information does the object have?**			

	Type of information			
	itself	**Context (environment)**	**Final user ***	**other objects**
Structural knowledge (the physical / digital structure of the object).	Material in which it is made Sensors and actuators it has	Other objects in the environment	Physical characteristics of the user	Interfaces offered by other objects
Teleological knowledge the goal (s) an object is designed to have	Decrease elderly sedentary lifestyle Detect posture and parameters	General environmental goal (improving health, saving energy, ...)	User goals (move more)	Objectives of other objects
Functional knowledge (the functions the object / context / user can perform to reach its goal (s), "what the * can do"),	Collect data on how long user is sitting ..	Coordination of actions to reach the goal (turn off all lights, do not turn on air conditioning,.)	Things the user can do	Activities that other objects can do
Behavioral knowledge (the way a specific function is executed, ie, the actions that the object performs when a function is activated, "how to do")	How the data is collected, how it behaves (vibration, message to the caregiver ..)	How coordination takes place	Activities that the user must do (for example, a walk of half an hour a day, drink every hour ..)	Specific behaviors

REASONING LAYER	**Type or reasoning used (for example,** (i) deductive (ii) abductive, (iii) inductive (iv) analogical, (v) common sense ..). If there are learning capabilities	If the object is intelligent, how does it reason. If you learn, what and how you learn	..

Figure 2: Example of the ARSPO's layers adapted to EUD.