Rethinking the Design of Enriched Environments

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Abstract. Most advances in pervasive computing focus strongly on technological issues (e.g. connectivity, portability, etc.); as technology becomes more complex and pervasive, design achieves a greater relevance. Inadequate design leads to unnatural interaction that may overload users, hampering the old aspiration of creating transparent artifacts. Transparency is a concept that describes technology that allows users to focus their attention on the main activity goals instead of on the technology itself. Transparency is strongly related with the relevance of individuals' goals, their knowledge, and conventions learned as social beings. This paper aims to provide a framework for the design of augmented artifacts that exploit users' knowledge about how things work in the world both in the syntactic and the semantic level.

1 Introduction

The goal of ubiquitous computing is to "to make a computer so imbedded, so fitting, and so natural, that we use it without even thinking about it" [21]. The challenge is faced through various approaches. For instance, context-aware computing aims to enrich the environment so that applications can recognize their situation and adapt itself in a proper way [1]; through tangible user interfaces people may manipulate the computational power through enriched physical devices [7, 9]. In mixed reality, physical objects in the environment are enriched with information and have a virtual representation in the virtual world [11]. In instrumented environments, computing power is embedded into everyday artifacts, augmenting their capabilities [16].

Initial efforts on these areas have focused mainly on technical issues ranging from communication and architectures to possible applications. The achieved improvement had generated new technologies so that computer disappearance is closer. Such disappearance could be physical (miniaturization and integration into everyday objects) and mental (enriched objects do not draw our focus of attention towards them) [15]. However, the latter issue is complex and not yet fully solved. Core issues are related to interaction design, environment sensing, context modeling, resource discovery, privacy and security as well as infrastructure [15, 1].

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Design achieves a center stage for allowing a seamless interaction between people and the computational infrastructure, so that computers can mentally disappear or become "transparent". Transparency [21, 2, 15], claims that a well-designed artifact (such as a door) becomes transparent when used if it allows us to focus on the task at hand instead of on the artifact itself (e.g. a door allows us to focus on our plans when getting into the kitchen instead of on the door itself) [2]. In order to achieve such transparency an object must exhibit some properties that exploit the human cognitive system such as affordances, feedback, and user's knowledge [10].

Inadequate designs lead to unnatural interfaces, hard to understand, requiring an extra cognitive effort from users for learn how to manipulate them (syntax), and interpret the result of such manipulation (semantics). As a result, there is not a clear understanding of users' needs, restrictions, knowledge and assumptions in relation with the interface. How does the interaction between humans and these kinds of artifacts should be defined? What features of the settings and artifacts must be considered when designing? How can people discover and interact through the active elements of an augmented environment?

In this paper, we present a framework for guiding the design of enriched artifacts. Our approach follows a cognitive stance that aims to understand and exploit user's knowledge beyond artifacts mere manipulation. We recognize that users assign meaning to objects based on its context of use [2]. Particularly, Everyday Objects (EO) such as keys, doors, rooms, etc., has a meaning shared by a specific community. Users have expectations about them: a lawyer may expect to find his door office closed, while students may expect to find their room door opened.

The work presented here draws from previous experiences that allowed us to refine extensively our first approach. We also apply our framework for guiding the design of an enriched everyday object, which is a portrait. The rest of the paper is organized as follows: section 2 elaborates on the conceptual background and relates it to other approaches. Section 3 shows the proposed framework. In section 4 we apply the framework in a practical example, and finally, in section 5 we present some conclusions.

2 Related Work

Norman [10] provides a guide for understanding objects functioning from a cognitive point of view. He defines concepts such as affordances (things' properties determining its manipulation), constraints (thing's properties prohibiting some activities and encouraging others), feedback (thing' properties informing users about actions performed), etc. Norman's concepts describe object manipulation, but they are too general for enriched artifacts design where users' expectancies about manipulation may be completely diverse. In addition, they are mostly related to the objects' physical properties neglecting the cultural understanding about how objects are supposed to be manipulated and work, that is, the objects' context of use [4].

There is no consensual definition about what is context or what it comprises. In a broader sense, it can be understood as "the interrelated conditions in which an event, action or situation takes place" or as "a complex description of shared knowledge within which an action or event occurs". Context definitions seem to agree in two aspects: First, context comprehends everything that surrounds "something" (e.g., situation, an activity, an idea), but is not the thing itself. Second, context embraces a set of interrelated elements that maintain a coherent relationship, providing a particular meaning to the thing [2, 13].

The need of proper design can be also observed through the recent papers regarding evaluation of ubiquitous computing using ethnomethodology methods [5, 19], or analyzing the field development [1, 15]. Although insightful, such approaches are insufficient for supporting artifacts' design. Another approach followed by Hong et al. [8], propose a requirements elicitation methodology for supporting context-aware applications design in ubiquitous environments. The methodology have seven steps (identify target groups, estimate typical contexts involved, enlist requirements for each context, determine users' activities while using the system, identify context impact on such activities, detail the context-aware capabilities, compare capabilities with requirements) that allows a progressive analysis of the contexts that will occur when the application runs. Unfortunately they mainly consider physical context but include as well, few concerns about the context of use.

Finally, Theofanos et al. [17] grounds a framework for evaluation of UbiComp applications where they identify nine areas of evaluation. The framework considers cognitive (attention, conceptual models, interaction), social (adoption, trust, impact and side effects), aesthetics (appeal) and computational aspects (robustness) of applications. From those, we are mainly interested in the cognitive and social aspects and its impact when designing an application. Next section considers the revised concepts (Norman's concepts, context of use and evaluation) for defining a framework for the design of enriched artifacts in instrumented environments.

3 Framework for Enriched Artifacts Design: Syntax and Semantics

We define the context of use as the interrelated conditions in which an individual interact *purposely* with such object. Such conditions can be differentiated at least in two complexity levels: the manipulation or actions performed by users on the object (*syntax*) and the interpretation of its results (*semantics*).

Based on a previous work [3] as well as the work of Theofanos, Norman and Hong, we have defined a set of dimensions of analysis (DOA) for each category (syntax and semantics). Such dimensions allow us to describe an everyday artifact syntax and semantics, decide which of them will be changed and afterwards analyze the choices' impact when users interact through the artifact. Some dimensions belong to both the syntactic and semantic category, but in each one they have different meaning. Syntactic DOAs aims to understand an objects manipulation from various perspectives, while semantic DOAs allow designers to understand the users' higher goals when using the artifact. Table 1 provides a brief description of each DOA. DOAs themselves are composed of sets of dimensions.

Table 1. DOA Model. The table shows the detailed description of each DOA.

Category	DOA	Description
Syntax	Manipulation	Describes the object's physical manipulation, the attributes expected to change, and the caused changes. It includes the Usage, Feedback, Intention, Consequence, Action, and Opportunity dimensions.
	Attention	Describes users' attention pay to the object, and the physical features that generate focus change. The following dimensions compose this category: Focus, Interrupt, and Overhead.
	Accessibility	Describes the physical access to the object. The following dimensions compose this category: Access, Privacy, Control, Roles, Reach, and Transfer.
	Restriction	Describes the physical restriction of the object. The following dimensions compose this category: Dependence, Cost, Availability, Flexibility, Past History, and Scalability.
Semantic	Conceptual Model	Describes user's conceptual model about the object, the meaning assigned to the object by certain community. It includes the Opportunity, Intention, Consequence, Action, History, Relevance, Value, and Exclusivity dimensions.
	Accessibility	Similar to syntax's accessibility with an emphasis on the meaning of having access to the object. The following dimensions compose this category: Access and Privacy.
	Restrictions	Describe no tangible restrictions of the object. The following dimensions compose this category: Knowledge and Dependence.
	Attention	Similar to the syntax's attention, but with an emphasis on the meaning of paying attention to the object. The following dimensions compose this category: Focus, Interrupt, and Overhead.

3.1 Everyday Objects Syntax and Semantic Modeling

Our aim is to design physical environments that include everyday objects augmented with new features. Our first step is to determine which objects will be considered as

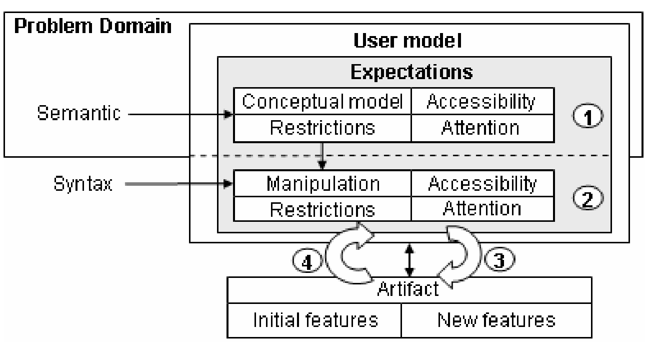

Fig. 1. An outline of the user model

part of the environment. One of the risks when augmenting objects with new functionality is that we distort objects' syntax and semantics in a way that we lose useful properties or change the object so much that users may need extra cognitive effort to use it. In order to avoid this, we model the object real syntax (manipulation) and semantics (interpretation) using the dimensions defined in Tables 1 (numbered circles 1 and 2 in fig, 1). In this way, we can perform later a controlled distortion. Is up to the designer to define how many times the analysis-distortion cycle will be performed. It will depend on the uncertainty of the wanted effects. Due to space limitation we will briefly describe the most important in Table 2, the others dimensions are self-explanatory.

Table 2. Description of the most important dimensions of the Syntax and Semantic Models

Syntax Model		
DOA	Dimension	Description
Manipulation	Usage	Describes the mechanism for manipulating an object. (Norman's affordance concept).
Attention	Focus (Gaze)	Provides information when a user needs to focus in the object.
Accessibility	Control	Describes the ability of users to manage who can use an object.
Restrictions	Scalability	Provides information about number of objects that is possible to have.
Semantic Model		
DOA	Dimension	Description
Conceptual Model	Opportunity	Describes when an object is used.
Accessibility	Access	Describes who can use the object.
Restrictions	Knowledge	Describes the necessary knowledge to use an object.
Attention	Overhead	Provides information about workload imposed on the user due to changing focus.

3.2 Augmented Objects

Previous phases, aims to identify the objects to augment, their physical restrictions and manipulation constraints as well as the expectations hold by each type of user in relation with each object. Now we can define the objects new features (numbered circle 3 in fig. 1). These features should be consistent with the syntax and semantics defined in the previous steps. A designer may choose to change some of them, but s/he will know in advance if users may need to learn to use these new features.

As well, a designer may choose to modify an object (numbered circle 3 in fig. 1). For instance, s/he could add leds, speakers, motors, etc. Again s/he should consider the impact of his/her choice on syntax and semantics. If the object is modified, then its physical constrains and manipulation could change. Furthermore, users may decide to change their shared policies in order to take advantage of objects new possibilities. In this case the cycle must be followed again (cyclic arrows numbered 4 in fig. 1).

Table 3. Syntactic and Semantic model for a portrait. A detailed analysis of most important dimension allows the understanding of its manipulation and the shared meaning.

		Syntax Model	
DOA	Dimension	Question	Answer (Portrait)
Manipulation	Usage	How do you handle a portrait?	Putting the photograph in the portrait. Locating the portrait on a visible place facing towards me.
	Feedback	How do you know it is working well?	Because the photograph fits to the portrait and I can see the picture.
	Intention	What do you intent when operating the portrait?	That it holds a picture and I can watch the picture later. That it remains where I put it on. That it faces me.
	Consequence	What is the direct consequence of using a portrait?	It remains in the last place I put it on. It shows the last picture placed there.
	Action	What do you do with a portrait?	Hold the portrait. Put pictures on it
	Opportunity	When is a portrait used?	When I want to see a picture. When I want to show a picture to other people.
Attention	Focus (Gaze)	When do you focus on the portrait?	When I look at it.
	Interruption	When are you interrupted by the object?	Never.
	Overhead	When do you need to put attention on the portrait?	Only when *I want* to see the picture.
		Semantic Model	
DOA	Dimension	Question	Answer (Portrait)
Conceptual Model	Opportunity	When is a portrait used?	When I want to remember "loved beings" or "unforgettable moments".
	Intention	What is the user intention when have a portrait?	Providing a constant reminder of the feelings and emotions associated with this person or moment.
	Consequence	What is the direct consequence of using a portrait?	Providing a constant reminder of the feelings and emotions associated to that particular time frame or circumstances.
		Syntax Model	
DOA	Dimension	Question	Answer (Portrait)
	Action	What do you do with a portrait?	Watch the picture hold by the portrait. Get close to the picture and grab it
	History	How do you know if a portrait was used?	When the picture or location has changed. When my emotions distort the picture.
	Relevance	What is the relevance with a portrait?	Emotional. It maintains bonds with people, animals, places, etc.
	Value	What kind of value has a portrait for me?	Emotional, personal.
	Exclusivity	Is the portrait able to be replaced?	Maybe, by a framed picture on the wall...

4 Applying the Model

In this section, we apply the proposed framework for augmenting an everyday object, namely a portrait. Photographs are an important part of many people's life; they arrange their personal pictures on their desks and around their homes. For example, photographs of "loved beings" or "unforgettable moments" are symbols of a personal bond and provide a constant reminder of the feelings and emotions associated to that particular time frame or circumstances. Emotions [6] and cultural expectations about handling a portrait are the basis of the syntactic and semantic models of Table 3.

4.1 Augmenting a Portrait

The previous analysis of portrait's syntax's and semantic dimensions shows that this particular everyday object is strongly related to emotions. Emotions are a social need, representing an important channel of communication with one-self and others (e.g. reminding someone, showing loved persons or situations to others). This kind of communication can be difficult at a distance, because of the limitation of physical access to the others' personal space. This analysis makes us wonder *whether by augmenting an everyday portrait with computational capabilities we could support the affective communication at distance.* Hence, we decided to create a physical augmented portrait maintaining some syntax and semantics but disregarding others. Table 4 presents some dimensions that changed base on our design choices.

Table 4. Design choices for an augmented portrait in both syntactic and semantic categories

Syntax model			
DOA	Dimension	Question	Answer (Portrait)
Manipulation	Usage	How do you handle a portrait?	Connect the portrait to PC. Putting photographs that represent *each emotional state* of only one person in the portrait.
Attention	Interruption	When are you interrupted by the object?	When any emotional state is arriving and change the picture associated with the emotional state. When a light blinks, indicating that an emotion has been received
Semantic model			
Conceptual Model	Opportunity	When is a portrait used?	When I *want to* communicate the feelings and emotions for the person related with the photograph contained in the portrait. When I *want to* see the current emotional state of the person related with the photograph contained in the portrait.
	Value	What kind of value has a portrait for me?	Have emotional awareness. Communicate several tokens of affection in a semi-transparent way. Interpersonal communication.

The described choices were considered for enriching an everyday portrait. A physical device and a GUI equivalent were developed. Figures 2 depict the device and the application respectively.

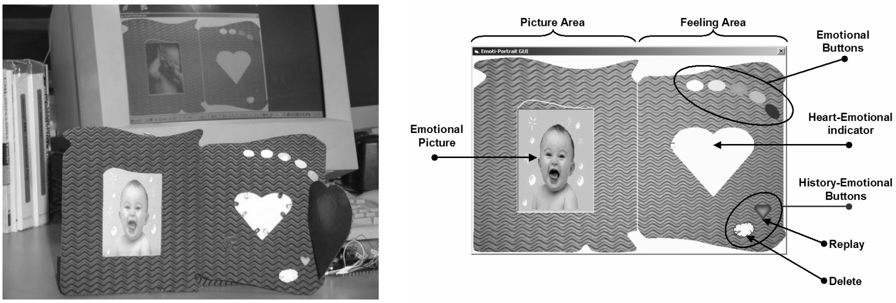

Fig. 2. The new chosen features are implemented in the portrait

Figure 2 describes the virtual features that we have chosen for augmenting a portrait in order to support affective communication. The augmented portrait has been designed to be used like an everyday picture frame, showing pictures of loved beings. It has two main parts: (a) a picture area, showing a picture representing an emotional state of a remote person, and (b) a feeling area, containing Emotional Buttons, a Heart-Emotional Indicator and History-Emotional Buttons. When the user wants to transmit some feeling, s/he has to press any Emotional Button. Each colored button represents some emotional state; they provide information about the local emotional state (e.g. blue color represents a melancholic emotional state) [12, 14, 18, 20].

When any emotional state arrives to the augmented portrait, it pop-ups a picture representing the emotional state received. The red light located around the Heart-Emotional Indicator, will blink, indicating that an emotion has been received. If a user wants to communicate the emotion "I'm thinking about you", s/he must touch the picture located in the Emotional Picture zone. Then, the augmenting portrait will shows a picture with green light blinking indicating that an emotion has been received. The user can stop the blinking of the Heart-Emotional Indicator, simply by touching the surface of the heart.

Additionally the user can block the reception of emotions by closing the portal of the Heart-Emotional Indicator, this action is never informed to the other user and all the emotional states that are received after such action are stored in the history database for a later optional recovery. The prototype developed, called Emoti-Picture Frame, allows anyone with Internet access to transmit their feelings as a way of communicating emotions and displays them on a Tangible User Interfaces (TUI) a Graphical User Interface (GUI) interface or both. The TUI and the GUI interfaces are shown in Fig, 2, left and right side respectively. The TUI version is designed as component Phidgets [7] and the GUI, developed in C#, is composed from the information generated by the Phidgets through APIs provided by the respective supplier.

5 Discussion and Conclusions

A common problem when designing new interfaces and tools in the pervasive computing field relies in the analysis stage. It is hardly questioned which interaction features are effectively supported and which ones will require users' to learn new styles of interaction. We face the problem, by providing an analysis framework that allows identifying several interaction aspects involved in the design of these new solutions. The framework embraces various dimensions in the syntactic (all the information about both object management and its physical features) and semantic (all the information about the meaning we give the object and its usage) levels.

An advantage of the proposed methodology is that it allows defining a priori the impact of augmenting an artifact with new features. Such impact could be stated both in the syntactic and semantic level. In addition, designers may choose to create radical ways of interaction that distort the artifact strongly. Our approach does not limit design forcing them into the traditional way an artifact is used, but provides a framework for understanding the consequences of the design choices.

For guiding the design, analysis dimensions have been categorized in several topics such as Manipulation, Restrictions, Conceptual Model, Access, and so on. Notice the differences on the impact produced when modifying the dimension form one category to another. For instance, modifying the Conceptual Model of some object can be much less desirable than modifying its Restrictions. This will help designers to make informed decisions for its deployment and also permit users adopting and taking benefits from the augmented object. A frequent problem is having objects that are unnatural in its use; the lack of the proposed analysis impedes the understanding of the user's mental model about the object.

The proposed methodology should be used together with other design procedures such as Hong's strategy in order to define which is the ultimate goal of the design, what kind of need will the artifacts satisfy, providing a complex spectrum in the development of augmented objects. A lot of effort is put on products evaluation, however, objects design must be immersed in a methodology that guarantees that the development of new tools is effective and include all the involved factors in the use of this kind of tools. A second stage of research will include the definition of formalism for design based on UML.

Further work is required in order to determine which are the best candidates for augmentation, which are the best techniques for augmenting some features but maintain the "naturalness" of use, which are the relationships among the dimensions described by the paper, and defining adequate evaluation mechanisms. We expect that the present work contribute with such goals.

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