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Developing Augmented Objects: A Process Perspective

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Abstract: There are many examples of augmented objects in the literature. Augmented objects should provide intelligence to the ambient where they are located and also they must require a low cognitive effort to be used. Few works have been reported providing guidelines to conceive and design these components. Therefore, developers have to use improvised ad hoc software processes to support the development of augmented objects. In order to help dealing with this situation, this article presents a software process to develop these components. The proposed process was named Augmented Objects Development Process (AODeP) and it is based on the authors' previous experiences and software engineering best practices. The article also reports two case studies in which AODeP was used to guide the development of augmented objects in specific problems. The obtained results are encouraging.

Keywords: Augmented Objects Development, Ambient Intelligence, Software Process
Categories: D.2.2, D.2.10, H.5.2

1 Introduction

Recent advances in computer science and ICT technologies have introduced new technological solutions to make life easier for people. During the last years, the users of computers have been limited to utilize classic interfaces (i.e. using a keyword, mouse and a screen) to interact with computational systems. However, new computing concepts, such as Ubiquitous Computing [Weiser 1993] and Augmented Objects [Ishii et al. 1997], have provided novel ways to interact with computers and also new scenarios to use these systems. These computing concepts provide intelligence to a physical ambient that adapt itself to the needs, tastes, and interests of the people who live within those environments, and help them to carry out all kinds of tasks related to their daily life, work, leisure, etc. [Abascal et al. 2007]. Typically these solutions involve socio-technical components.

This article addresses the challenge to conceive and design augmented objects, which is a particular way to provide ambient intelligence (AmI). Ishii et al. defines an augmented object as a common object, which has been provided with additional functionalities through integrated computing or software systems [Ishii et al. 1997].

Several augmented objects have been developed during the last years in order to support activities in various areas, such as health [Bravo et al. 2008, Gasca et al. 2009, Villarreal et al. 2009], education [Patten et al. 2006, Ryokai et al. 2004, Ananny and Cassel 2001] and daily life activities [Aguilera et al. 2006a,b, Alaman et al. 2007, Sanchez et al. 2008]. Every day these object become more and more common and available for the people. However, the development of these components is a real challenge because it involves several socio-technical issues. For that reason, users' participation during the development process is vital.

After an extensive literature review, the authors have not found reports of proposals to support the development of augmented objects from a software engineering approach. However there are various interesting proposals that support the development of ubiquitous and pervasive systems, which could be adapted to be used for augmenting objects. Although these proposals involve requirements similar to those involved in the object augmenting process, a more depth inside about the adaption process is required in order to know how to use them properly. This need for easy to use guidelines pushes developers to use improvised ad hoc development processes, which consequently are typically expensive and non-reusable. These processes could also impact the suitability and effectiveness of the obtained objects.

In order to help dealing with such situation, this article proposes a systematic process to develop augmented objects based on the authors' previous experiences and software engineering best practices. This process, which was named Augmented Objects Development Process (AODeP), uses knowledge from several disciplines (e.g. human-computer interaction, software engineering, and industrial design) to support the development of this type of components. AODeP has been tested through several case studies; two of them are presented in this article.

In the first case study, a set of phidgets was used to augment a pencil holder that embeds a clock. Such object is used by the manager of a Chilean accountability company to know the progress of the accounting processes they perform for the clients. The second case study augmented a portrait to make it able to transmit feelings. Such object was developed and used by foreign students at the Computer Science Department of the University of Chile, in order to help keep the link with their relatives and girlfriends, whom live far away.

Next section presents and discusses the related work. Section 3 describes the proposed process. Sections 4 and 5 present the cases studies in which the AODeP was used. Such sections also report and discuss the obtained results. Finally, Section 6 presents our conclusions and future work.

2 Related Work

An important number of Augmented Reality (AR) experiences have been reported in the literature. The experiences show how AR can be used to support interesting activities in several application areas. In this section we report some of these experiences and present and discuss the research work related to the development process of ubiquitous, pervasive and AmI systems.

2.1 AR on Education

An example of a system that supports education using augmented objects is Audiopad [Patten et al. 2006]. It uses an augmented table to support teaching of music. This system monitors the movements of various objects presented on the table surface and transforms those movements into commands. The commands are received and interpreted by a synthesizer, which finally transforms the commands into sounds.

Other interesting project is I/O Brush, which augments a brush to help children from four years to explore and discover colors and textures from the surrounding objects and movements for painting [Ryokai et al. 2004]. This brush has a small camera with lights and a motion sensor. Outside the drawing room, the brush is able to capture colors, textures and movements of the surface on which it travels. Then, using these elements the children create their own draws.

In the TellTale project [Ananny and Cassel 2001] authors have augmented a toy like a centipede to help children to develop narrative skills of school children. The centipede has five sections; one of them is the head and the others correspond to the body. Each child tells a part of a story to one part of the body, which eventually joins. By putting the head in place, "TellTale" tells the whole story. The story can change simply by interchanging body parts of the object.

The PlayPals project reports a system designed to be used by children between 5 and 8 years old, which have to learn to collaborate using a virtual environment [Bonanni et al. 2006]. The remote interaction among the children is performed through avatars (one avatar per child) that react with the children movements.

2.2 AR on Healthcare

Several research works have been done in order to provide ambient intelligence to hospitals and others facilities related to healthcare activities. For example, in [Sanchez et al. 2008] authors proposed a system that represents a smart physical environment to automatically estimate hospital-staff activities. Its goals are: (1) to provide a tool that allow hospital managers to understand the work dynamics and identify issues to be improved, and (2) to provide a set of context-aware applications to medical staff.

Bravo et al. propose a solution to improve and complement Alzheimer’s care based on the use of NFC (Near Field Communications) and DTT (Digital Terrestrial Television) [Bravo et al. 2008]. Using this solution caregivers can remotely monitor patients and interact with other healthcare personnel through NFC enabled mobile phones. These researchers also present a complementary system for Alzheimer care, which includes visualization of activities at home.

Villarreal et al. [2009] propose a mobile monitoring system that allows patients with diabetes to have a constant control of their glucose tendency as well as direct communication with their physicians. This system eases patients’ lives and increases the monitoring and control activities performed by patients and physicians.

Gasca et al. [2009] describes a persuasive system aimed at promoting a healthy lifestyle in patients with a chronic disease whom participate in a supporting group. Such system binds the ideas of persuasive computing [Fogg 2002] and virtual communities in order to obtain a solution able to support interactions between health specialists and the community members (i.e. patients).

Misook and Jeunwoo [2007] propose an Instant Messaging system that shares context information relating to health and covering things such as physical activity and smoking behavior. The system, named UP Health (Ubiquitously Persuasive Health Promotion), includes special features (e.g. advises, alarms and notification) to enhance healthy behaviors of the people.

2.3 AR at Home

Concerning AR at home there are also several interesting initiatives. For example, Alaman et al. [2007] describe various projects for home-oriented AmI environments developed in Spain. These projects include: (1) a prototype of a smart living room which include several sensors and actuators in order to manage the ambient behavior based on a set of rules, (2) an AmI environment named Plan B, which is based in a novel operating system, and (3) identification technologies (e.g. RFID and NFC) to provide intelligence to a physical environment.

Aguilera et al. [2006a] proposes a desktop-lock system to indicate users' presence in a physical environment. This system augments the traditional door-lock system by using an augmented key. It allows users to open and close virtual shared workplaces and show/hide their presence to other users connected to the shared space. Unlike the real world, virtual desktop-locks are not associated with just one key, but with many keys as long as they belong a valid virtual workplace for a user. Aguilera et al. [2006b] also designed an augmented picture frame, that allows anyone with Internet access to transmit their feelings as a way of communicating emotions. The development of this application is analyzed more in depth in section 5.

The Massachusetts Institute of Technology (MIT) has a major initiative named House_n [MIT 2010]. Such initiative hosts several projects that explore the use of technologies to provide intelligence to physical environments and their components. Thus, researchers try to respond to the needs of people that live technological environments. Georgia Tech's Aware House (www.cc.gatech.edu/fce/ahri) and Ericsson's intelligent condominiums (www.e2-home.com) are other relevant initiatives similar to House_n.

2.4 AR on Sport Clothes/Accessories

There are also examples of commercial augmented objects. Nike and Apple have developed an extension to the MP3 player iPod, which allows users of Nikes sport shoes (compatible with the system) to keep statistics of the traveled distances and times involved in exercise activities [Nike 2010]. By synchronizing the iPod with a host system (running in a PC), users can get a full history of the performed exercise.

Adidas in conjunction with Polar (a company specialized in sport watches) have been conducting a similar initiative named "Project Fusion" [Adidas 2010]. Such project designs a sport watch able to measure several variables from a person (e.g. time training and heart rate) when s/he is using particular models of Adidas t-shirts.
Motorola and Burton companies developed the Audex Jacket [Motorola and Burton 2010]. This jacket allows users to answer phone calls through these garments. Another company, Oakley, a maker of sunglasses and clothing for extreme sports, has developed sunglasses models that incorporate a hands-free Bluetooth headset to be used with Motorola cellular phones [Oakley 2010].

2.5 AR in the Military Context

There are many examples related to the use of Augmented Reality in the military context, especially in the field of simulations and military training [Livingston et al. 2002]. For instance, Yen-Hung et al. [2008] describe several AR techniques for the visualization of robotic helicopters performing field tasks. Henderson and Feiner [2009] shows the design, implementation and testing of an augmented reality prototype application that supports military vehicle’ mechanics.

There are also research works reporting the use of AR to visualize military operations in field. These applications require video cameras and eye tracking systems to provide additional information to the users [Park et al. 2008]. Typically such information is related to particular objects (including other participants) that are in the physical context of the user.

2.6 Development of Ubiquitous/Pervasive Systems

There are several interesting proposals for developing ubiquitous and pervasive systems, which could be used by AO designers to conceive new solutions. For instance, Chen et al. [2004] proposed an ontology called SOUPA for designing and model pervasive computing applications. Henricksen et al. [2002] propose a model of the context concepts for pervasive computing. Arroyo et al. [2008] present a design model to develop ubiquitous e-learning Systems.

There are also several middleware platforms that allow the development of these systems following a component-based [Becker 2004], aspect-oriented [Fuentes et al. 2006] or service-oriented approaches [Lopez de Ipiña et al. 2006, Ibrahim et al. 2007].

Although these proposals have shown to be useful to support the design and development of ubiquitous and pervasive systems, it is not clear how to adapt these solutions to make them applicable for augmenting objects. Typically AO designers require simple and easy to use guidelines; therefore this promising approach still requires some extra effort in that address to become it useful for augmenting objects.

2.7 Development of AmI Systems

“Ambient intelligence (AmI) is an exciting new information technology paradigm in which people are empowered through a digital environment that is aware of their presence and context and is sensitive, adaptive, and responsive to their needs” [Ducatel et al. 2001]. “It proposes a shift in computing from the traditional computer to a whole set of devices placed around us providing users with an intelligent background” [Bravo et al. 2006].

The development of these systems is closely-related to the design and implementation of augmented objects. An intelligent ambient can use one or various augmented objects in order to provide individual or collective services to the users. The goal of the Aml spaces and the augmented objects is the same: applying technology to support specific activities of our life, considering the final user as the most important concept, and making the technology an invisible presence [Vázquez and Lopez de Ipiña 2005]. Clearly several features of the AmI design processes can be extrapolated to help design Augmented Objects.

In the same way, the “Internet of Things” (IoT) approach [Welbourne et al. 2009] tries to extend the Internet into our everyday lives, using capabilities provided by wireless networks and RFID-tag objects. These tags help identifying people and objects, and also provide additional information from/to them. These capabilities are useful to monitor the environment conditions and users activities (i.e. to identify who, when, where and what) [Bravo et al. 2006]. Researchers envision that most physical components of an environment (i.e. objects and persons) will contain tags that help provide intelligence to our environments in the near future [Lopez de Ipiña et al. 2009]. Such components, including augmented objects, will be part of this future.

3 Augmented Objects Development Process

The process of augmenting an object is usually part of a larger software project that includes to augment one or more objects, and also to create several software components around of them, in order to solve a particular problem. Therefore, the development of augmented objects must be embedded as part of the regular software process that is used by the development team to reach particular objectives. Since the augmented object definition requires an important participation of the users, evolving software development methodologies or agile processes are strongly recommended. Figure 1 shows the Augmented Objects Development Process (AODeP), which can be combined with agile software processes in order to guide the conception, design, implementation and testing of augmented objects. This systematic and iterative process is driven by the users' feedback and it involves the six stages shown in Fig 1.

The AODeP process starts identifying and analyzing the problem to be solved through the use of an augmented object. It tries to understand the real problem and avoids falling into development processes guided by problem symptoms. Based on such information, developers will be able to determine most functional requirements to be considered during the augmented object (AO) design and implementation.

The analysis of the AO usage context is the second step. Such analysis provides contextual information about the physical workplace where the augmented object will be used and also about the users' general capabilities and skills. This analysis provides most non-functional requirements to be considered during the AO design. Particularly, HCI requirements and restrictions are obtained from this activity.

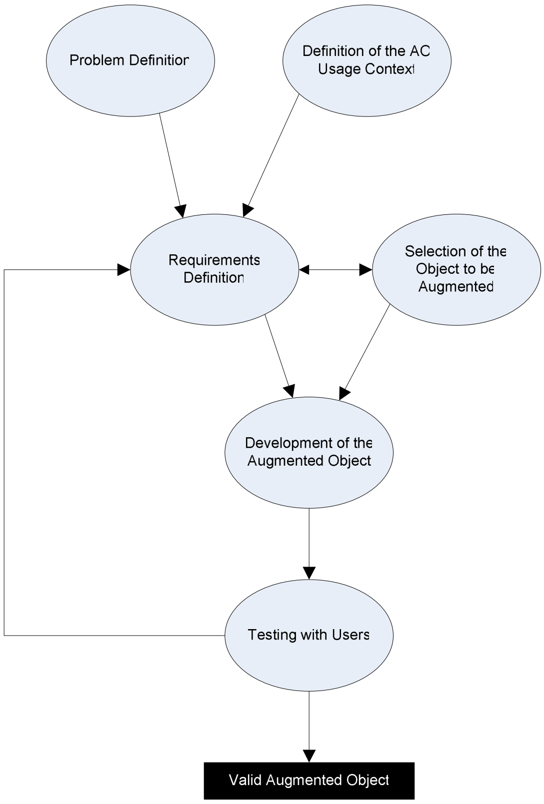

Figure 1: Development process of an AO

Similar to any software project, functional requirements (initially gathered from step 1) and non-functional requirements (gathered from step 2) are interrelated. It means that considering some functional requirements usually affects (i.e. positively/negatively) the accomplishment of non-functional ones, and vice versa. Therefore during the third step, developers have to define the set of requirements that must be considered during the AO design and implementation processes.

During the fourth step, the object to be augmented must be selected. This selection process considers the set of requirements identified in the previous step and also a study of the regular objects available in the workplace, in order to determine which element is the most appropriate to be augmented.

The fifth step involves designing and implementing the augmented object according to the rationale generated during the previous stages. Since the augmented objects development requires an important participation of the users, it is recommended to guide development of this object by using small and simple prototypes. Such prototypes must be tested by the users (seventh step) and evolve according to the users' feedback. Thus, after some iterations the obtained object can be considered as a valid augmented element

The users' participation during the whole development process is vital to obtain useful and non-invasive augmented objects. It also helps reduce the development risks and increase the impact of the final solution. Next sections present a detailed explanation of the phases involved in the proposed augmented objects development process.

3.1 Problem Definition

The problem definition stage identifies limitations to overcome and opportunities to take advantage using augmented objects. An in-depth analysis of the situation is required to be sure the problem or opportunity is the right one and it is worth to be addressed.

The analysis of the problem must allow obtaining an initial set of functional requirements to be considered when developing the augmented object. This set represents the users' requirements, which provide a business view of the problem to address. It is recommended to work on a small and simple set of functional requirements to keep the project risk under control. For such reason, if the object to be augmented is complex and involves much functionality (e.g. a whole living room), it is recommended to use an incremental process. The main goal of the augmented object must be defined during this stage, and it must be established through a small, simple and validated set of users' requirements.

3.2 AO Usage Context

The problem context is highly relevant to determine the type of solution that will be more effective for a particular situation. An analysis of the problem context will allow developers to determine the set of non-functional requirements that must be considered in the solution. Examples of non-functional requirements are: the users' skills to interact with technology, the time periods in which the potential AO must be available for the users, the dynamic of the environment where the AO will be located and the AO users' routine.

Alarcon et al. [2006] propose a method to analyze the several contexts involved in computer-supported mobile collaborative work. Such analysis allows developers to determine functional and non-functional requirements involved into a software product. These researchers also propose a strategy to align functional and non-functional requirements [Guerrero et al. 2006]. Since these proposals are suitable to analyze the AO usage context and also to align the AO functional and non-functional requirements, authors recommend using these techniques to conduct this stage.

3.3 Requirements Definition

Using the information gathered in the previous steps, it is possible to establish a formal set of requirements that will be involved in the development of the augmented object. Users must participate in this definition; therefore, this set of requirements is sometimes the result of a negotiation process between developers and users. One particular issue that must be considered in this requirements list is the physical interaction mechanisms that are feasible for users, in order to use properly the augmented objects. In most cases these interaction mechanisms are so important that deserve special consideration to ensure the usability of the solution.

As was mentioned before, if the product is complex or involves much functionality it must be developed by increments. Each increment must include a particular set of requirements, which determine the project's scope, cost, risk and possible impact. In order to keep the project under control, this set must be kept as small and simple as possible; not only in this stage but also into the whole project.

Once the requirements are selected, they must be turned into features to be embedded into one augmented object. In order to do that, it is worth to create a metaphor of similar interaction characteristics to simplify the process of identifying the best real object to be augmented.

3.4 Selection of the Object to be Augmented

This stage of the process analyzes the set of requirements in order to identify the best real object to be augmented. This selection activity, which was defined in a previous work (see [Aguilera et al. 2006a]), analyzes the syntactic and semantic models related to each object that is candidate to be augmented. The syntactic model determines how we manipulate the object, and the semantic model establishes how we interpret their use. In both cases it is important to consider the physical nature of the objects that are candidate to be augmented.

Syntactic and semantic models of every object are developed by answering a set of questions related to twelve dimensions: usage, feedback, history, intention, consequence, action, dependence, opportunity, access, roles, reach and view [Aguilera et al. 2006a]. Each dimension must be analyzed at two abstraction levels: syntactic and semantic. This AO selection process is presented in-depth in sections 4 and 5.

Once concluded this analysis process, the developers could have more than one candidate object to be augmented. In such case, the decision about which object to augment becomes a decision that must be made in consensus between the developers and the users. Typically, the development time, cost, risks, and the effectiveness of each potential solution are variables that must be considered.

Sometimes the selected object is not fully aligned with the requirements specified in the previous stage. In such case, the project requirements must be adjusted according to the features of the object to be augmented. If the set of requirements cannot be adjusted, a new potentially augmentable object should be introduced into the environment, and it must be evaluated with the users.

Since this is one of the most risky stages of the development process, the matching between requirements and the potential augmented object should be evaluated. Typically this evaluation process is done by using a system prototype.

3.5 Development the Augmented Object

Since the augmented object design and implementation are challenging tasks that involve a high uncertainty, it is recommended to address them by defining and refining prototypes. It requires creating a quick prototype of the object, and testing it with real users. Usability tests are mandatory. The obtained feedback can be used to improve the object design and/or implementation. This process must be repeated more than once in order to be sure the project goes on the right way.

Several guidelines to conduct this stage are available in the HCI literature; however the most appropriate ones will depend on each particular project. AR toolkits and frameworks can be used to support this stage. Typically it helps to reduce the project cost, duration and risks.

3.6 Testing with Users

Testing with users must be done incrementally. During the project inception period, testing activities are oriented to explore and validate alternatives of solution. Fast prototypes (some of them in paper) are used to reach such objective. While the project evolves, the prototypes should become more complex and tangible (from a software system to a functional scale model representing the augmented object). All these interim representations of augmented objects must be tested with final users to be sure the objects will be appropriate to solve the problem. If the testing process is conducted properly, the impact of the final product should be previewed before to conclude the object implementation. Eventually, the testing process evidences some problems regarding the requirements or the object selected to be augmented. In such case, the problematic element should be reviewed. It is important to detect these situations early, because the cost of fixing it increases with the project progress. Next sections present two case studies that used AODeP to augment specific objects.

4 Case Study 1: Progress Indicator of an Accountability Process

This case study involved a Chilean accountability company, which provides services on bookkeeping (i.e. accounting), wages and tax advices, to health small and medium-size enterprises. The client company has a portfolio of customers that is managed by various accountants. Typically this is a 1-to-N relationship, where an accountant has to manage several clients.

In order to maintain a good quality of service and meet the schedule established by the Chilean Government's Tax and Revenue Service (TRS), it is vital for the company to keep the control over the progress of the accountability process related to each client. The TRS establishes the due dates (monthly) to submit the incomes and expenses declarations for several tracks of tax-payers. Based on such dates, each accountant must interact with his/her clients in order to obtain the information required to elaborate the reports. Accomplishing such deadlines is vital for the accountability company in order to avoid problems to its client.

The company organizational structure is composed of a manager (who is the owner of the company) and seven accountants. The manager, who has an extensive knowledge of all the processes, acted as the main user during this project.

4.1 Problem to Address

Typically each client has assigned a particular accountant, who is in charge of managing the relationship with the TRS. This feature of the accountability service is highly appreciated by the clients, and it represents an important competitiveness and marketing tool for the company. However it also represents a focus of problems for the company.

This lack of rotation between clients and accountants makes strong links between clients and the service provider. Every month the clients have to deliver the accounting information to the company by a due date. However, this information is usually incomplete or delayed. Most clients feel the strong relationship with his/her accountant allows them to submit the information after the due date. Unfortunately, it becomes the incomes declaration process into a rally. Every month, one week before the deadline, accountants have to extend their labor journey in order to complete this process. Accomplish the deadlines is mandatory.

In order to keep the process under control, the manager asks for information to accountants during critical periods. Although it is needed, such request overloads accountants and it does not provide the visibility required by the manager. For that reason the manager wants to count on a visual and easy to use tool that allows him to monitor the whole declaration process without interrupt the accountants work.

4.2 Usage Context

The company already had a software tool to support the accounting process. However this system does not indicate the degree of progress for each accountant. For that reason, this project should extend the legacy system to deal with this requirement. Additionally, the project has to develop a special tool (an augmented object) that allows the manager to monitor the process. The manager (and owner) of the company is an older person with important limitations for using new technology. Therefore, accountants deliver printed reports to the manager, who review them sited at his desk. Since the manager is limited to use technological solutions, the most appropriate approach was to augment an every-day object of his office. Using such object he should be able to monitor the progress of the whole process.

Several meetings were done to exploring this idea with the client and define a useful metaphor for him. The selected metaphor was: “to match the progress of the whole accounting process with the filling process of a fuel tank into a car”. If “empty”, it means no customers were served, and every client that is served “augments the fuel amount into the car tank”.

4.3 Involved Requirements

Extreme programming and AODeP were used as methodological frameworks to guide the development process. Next, we present the most important users requirements involved into the development of the augmented object.

- *Monitoring of tax payments* - The system must be able to show the current progress of the client’s tax payment process. It should be shown in two formats: (1) the summary of the whole process; and (2) a summary by accountant.
- *Monitoring progress of monthly provisional payments* - The system must inform the progress of the monthly interim payments from clients. It involves the same information deployment formats than the previous requirement.
- *Information access* - The information should be accessed through simple and intuitive actions, e.g. by clicking.
- *Information visualization* - The information should be deployed in a graphical and simple format, which must be easy to be understandable by the user.

4.4 Selecting the Object to be Augmented

At this stage, several elements available in the managers' office were analyzed in order to determine the most appropriate component to be augmented. This analysis was done using the technique proposed by Aguilera et al. [2006a], which analyzes the syntactic and semantic models related to each candidate object.

After analyzing the syntactic and semantic models of various objects, a pencil holder with an embedded clock (similar to the one showed in Figure 2) was selected. Table 1 shows part of the analysis conducted with this purpose.

The selected element was aligned with the interaction metaphor adopted in the usage context analysis stage. In addition, such object played an important role in the manager routine and its use involved a small cognitive effort for him.

Figure 2: Object to be augmented

Syntactic Model	**Question**	**Answer**
Use	How do we use a pencil holder with an embedded clock?	We put it on our desktop; in a place we can observe the clock and store pencils.
Attention	When do we pay attention to a pencil holder with an embedded clock?	We paid attention to it when we need a pencil, or when we want to know what time is it.
Control	Who have access to this object?	*To the clock*: Every people in the room. *To the pencils:* the owner of the desktop.
History	Who knows how to use this object?	People in the office know how to use this object.
Semantic Model	**Question**	**Answer**
Opportunity	What are the consequences of using this object?	*Clock*: When we use this object we know the current time. *Pencil holder*: we put all the pencils in a common place.
Access	How can we access this object?	We must put this object in a visible and accessible place (usually, in our desktop).
Previous knowledge	What do we must know in order to use this object?	We must know how to read the clock.
Cost	How much cognitive effort represents the use of this object?	We need to focus our attention on the object. The effort for reading the clock is "small".

Table 1: Analysis of the pencil holder

4.5 Development of the Object to be Augmented (first prototype)

In order to evaluate the idea to augment the pencil holder, a prototype was developed using a box and a set of phidgets (see Fig. 3). Using a services interface a phidget periodically asks for information to the company server. The server informs the status of the whole incomes declaration process. Then, the phidget uses a servo to move the clock hand, which indicates the process progress over one scale. It works as a petrol gauge and keeps the metaphor defined with the user.

Figure 3: Prototype of the Augmented Object, which use an USB port

Figure 4: Augmented pencil holder designed for the client

The prototype way tested for one month, and the preliminary results were highly positive. For that reason the development team started to design the final version of the augmented object (see Fig. 4). This augmented object is able to monitor the two processes defined in the requirements stage, i.e. tax payments and provisional payments processes. For each process, the object indicates the progress of such process (i.e. a summary of the accountants work) and also the progress of the work performed by a particular accountant. All functions are available just by clicking two buttons.

4.6 Testing with Users

The use of the prototype shown in Fig. 3 indicated the metaphor representing the process progress was right. It reduced the pressing the manager applied on the accountants. However this experience also put in evidence the need to count on more detailed information concerning the process. Particularly, the manager indicated the need of putting available all the requested information (specified in the user requirements) through the same user interface. The evolution of this prototype, i.e. the augmented object, was in charge of dealing with such requirement.

The augmented object was put into production, and the obtained results were according to the previous experiences and the users' and developers' expectations. Currently, this object plays an important role into the company.

The manager and accountants agree the processes continue being stressful, but now they are under control. The manager increased the visibility of the processes; therefore he can take early corrective actions in case he needs it. In addition, the manager does not need to ask for information to the accountants, because all information is online.

Accountants feel more comfortable with the available time to complete the process because they know that such time is now effective. In the previous work scenario, the accountants had to inform the process progress every day, depending on the uncertainty and stress of the manager. Therefore, the available time to complete the assignment decreased every day.

4.7 Involved Technologies

The implementation of the augmented pencil holder involved components of several phidgets kits [Phidget 2010]. These components included I/O boards, several sensors, switches, LEDs, sensor cables, RFID tags, motors and relays, among others. These phidgets kits include also a software library (written in C) that allows monitoring and controlling these components. Services provided by the library are accessible through an application programming interface (API). Applications that help augment objects can be written in several programming languages; in the examples presented in this paper such language was C#.

All phidgets can be connected to the computer using USB. Phidgets run as USB 1.1 low speed or full speed devices, and they are supported by USB 1.1/2.0 hosts. Every phidget has a serial number, which is unique. This feature allows software systems to address a specific device independently of the number of phidgets that are being used at the same time. A particular service named phidget manager is able to get a list of devices (and their serial numbers) that are active in a certain time period. These two particular services are highly valuable to augment physical objects.

5 Case study 2: Peer-to-peer Portrait

The second project in which AODeP was used involved a group of graduate students of a HCI course delivered in our Computer Science Department at the University of Chile. In this course, every group (composed by three students) had to define a final project. The group involved in this case study was composed by three students: two foreign students and one Chilean student from a distant city. When discussing about the project, they realize that all of them miss their relatives and girlfriends, whom live far away. Therefore, they decided to address this topic into their course project.

5.1 Problem to Address

These students decided to try to increase the personal feelings awareness between them and their relatives and girlfriends by using Internet as communication platform. This awareness involved the transmission of feelings and sensations to their relatives using a simple and natural mechanism. The involved people had particular routines and schedules to interact. In this way, the solution should allow asynchronous communication and it does not have to interfere with the current activities of the users. The students found that most well-known Internet-based tools, as email or social networks, were not usable for older persons (e.g. the parents and grandparents of the students). The solution to be developed must be accessible to people with an ample range of knowledge about the technology. Experienced users would be able to access the advanced services provided by the solution; while inexperienced ones would access just basic functions. Considering this restriction, the students decided to augment a common object in order to transmit emotional messages, expressing what they were feeling at that moment.

5.2 Usage Context

The final users of the augmented object would be these graduate students, their relatives and/or loved ones. The students' girlfriends, sons and sisters were young people and they were familiar with technology. The houses where the students' relatives and girlfriends were living counted with Internet connection. However, the students' parents were old people and –similar to the client of the previous project- they were very unfamiliar with the use of Internet and new technologies. The solution should be very easy to use in order to allow all the involved people to understand the message sent through the augmented object.

5.3 Involved Requirements

In this project the main functional requirement was clear enough: to send moods (how do I feel?) through an augmented object from students to their relatives, and hopefully in vice versa. The solution should be easy to access, understand and use. The solution must use Internet as communication platform and it must allow asynchronous communication among users.

5.4 Selection of the Object to be Augmented

After studying some common objects available in the users' physical contexts, students decided that a portrait was the best object to be augmented. Table 2 shows part of the analysis done when applying the methodology proposed by Aguilera et al. [2006a] to that object.

Syntactic Model	Question	Answer
Use	How do we manipulate a portrait?	We put a photo in the portrait. Then we put the portrait in a visible place, showing the photo.
Feedback	How do we know if the portrait works?	Because the photo fits in the portrait and we can see it.
Intention	What do we want when using a portrait?	We want the portrait shows us a photo. We want the portrait still in the same place, in front to the people.
…	…	…
Semantic Model	**Question**	**Answer**
Opportunity	When do we use a portrait?	When we want to recall loved people or special moments.
Intention	What is the intention of the user when using a portrait?	Keeping in mind particular persons or special moments. Feeling again some particular emotions.
History	How do we know if a portrait has been used?	When the photo change. When it is in a different place. When is clean.
…	…	…

Table 2: Analysis of the portrait

Students conclude the portrait was the best object to be augmented because its use produces the lower cognitive effort. Moreover, when we look at a portrait and see the photo inside, most of the time we can remember emotions related to such persons or the situation in which the photo was taken. This sensation increases if in those photos are relatives or friends. Thus, this object already achieves the objective in the real life. Therefore, the augmented object had just to control the feelings the users want to transmit, and then represent such feeling correctly through the interface.

5.5 Development of the Augmented Object

In order to evaluate this idea, students designed a first software prototype in which two portraits were connected through the Internet. Two different computers run the software that allowed users to share their portraits between them and transmit their emotions (see Fig. 5).

This software portrait was augmented with some features that allowed it to transmit the users' feelings. For example, a user is able to establish which photo of him/her must be shown in the remote frames for a certain time period. Thus, remote portraits deploying the picture of such person will show how does such person is feeling. Besides, some other buttons were added in order to show the "intensity" of the feeling (e.g. emotional buttons and heart emotional indicator, see Fig. 5). Such software prototype was tested with several users; all of them were young people.

After an adjustment process was able to transmit the feeling envisioned by the developers. Therefore, the next step was to build the augmented object prototype in order to evaluate it use with older persons (e.g. the parents of the students).

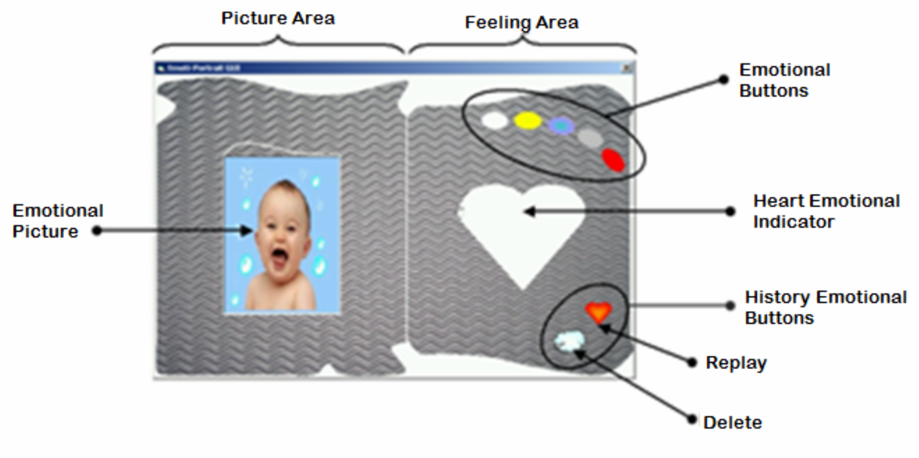

Figure 5. Software prototype for the portrait (augmented) object

Two portraits were built with such purpose. Every portrait was connected to a computer through an USB port. These computers were connected to Internet and run the portrait software version as well, as shown in Fig. 6. The portraits implementation involved the same technologies as the previous case study.

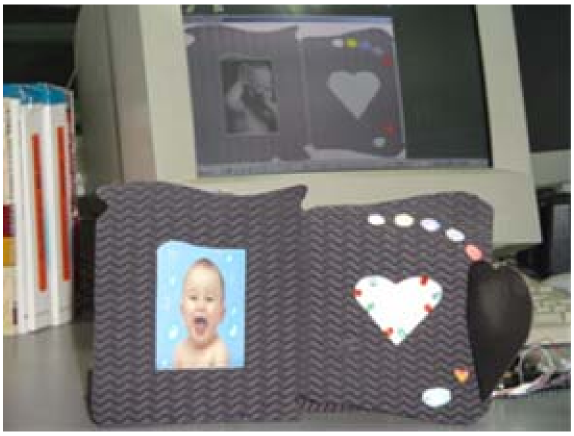

Figure 6: Prototype of the portrait connected to Internet by an USB port

5.6 Testing with Users

Initially a graduate student and his girlfriend (who lives in another city) used these augmented objects for a period of three weeks. Each person had a portrait connected to his/her own computer, which was showing the picture of the loved one. After using this augmented object, these persons increased the number of interactions among them. As an anecdote, our student said his telephone account experiment an important increment during this month, because his girlfriend asks him to call her every time she knows he was sad or worry.

After such experience, the portraits were used by a foreign graduate student (who was not part of the development team) and his parents. In this case, the parents had Internet in the house, but they do not know how to use it. Therefore, the student's brothers become as intermediaries among the graduate students and his parents. After using the portraits for a couple of months, it was possible to observe that the only one transmitting real feeling was the graduate student. His family transmitted just positive emotions because they believed that negative emotions could produce distractions and worries to the student work.

Although it does not work as was planned, it helped the whole family to keep connected. Every day (and sometimes more than once in a day) the graduate student and his parents sent their emotions through the peer-to-peer portrait. In addition, at least a daily email was sent among them. After a while, the students' parents were so interested in this type of communication that both of them learnt to use email just to be closer to their son.

6 Conclusions and Future Work

Developing augmented objects is a challenging task because it involve a large amount of uncertainty that range from technological issues to users behavior. Several interesting works have been reported by the augmented reality and ambient intelligent research communities. However these authors do not found proposals to address these developments as a systematic process, which considers lessons learnt and software engineering best practices. Therefore, we conclude that most of the current developments are being guided by ad hoc process.

There is much evidence in the literature that indicates the risks and disadvantages of developing with ad hoc processes. Some of the most relevant consequences that apply to the development of augmented objects using ad hoc processes are the following ones: (1) an increment of the project cost, risks and development time, (2) the uncertainty of the impact that can be obtained with the product, (3) the reduction of the projects success rate.

In order to help dealing with this situation, this article proposes the Augmented Objects Development Process (AODeP), a systematic process that guides the development of augmented objects based on the authors' previous experiences and software engineering best practices. AODeP has been used in various case studies; two of them were presented in this article.

The obtained results show the process is able to successfully guide the development of augmented objects. At the moment the experiences have been highly positive for users and developers. Unfortunately, the authors have been involved (in some way) in every project in which AODeP technique was used. Therefore, an issue to address in the future work is to observe projects conducted by third persons that use AODeP to guide the process. The feedback obtained from them will be useful to validate and improve the proposed technique.

In the next future we are planning to augment new objects in order to validate and customize the proposed technique. In such experiences, the physical objects nature will be strongly studied to determine if it is appropriate to include it in-depth as part of the proposed process. In this way, the authors envision such strategy could help Augmented Objects designers to identify some particular requirements that could be addressed directly by them, e.g., they can match particular kinds of requirements to functionalities that will be included in objects. Thus, it is possible to conceive "functionality patterns" that would ease the analysis of the candidate objects, by considering the physical context of the final user.

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