ArLive: Unified Approach of Interaction Between Users, Operable Space and Smart Objects

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Figure 1. ArLive allow users to create predefined behavior. (*Left*) ArLive prototype composed of a desktop lamp and a light switch. (*Middle*) People interacting with the prototype. (*Right*) Close-up of the see-through augmented reality interface.

ABSTRACT
Smart objects and Internet of Things have become increasingly prevalent but expand without standard. Connected to the Internet but used as only as input devices, objects don't take advantage of this network to adapt their functionalities to users environment and digital life but behave in a predefined way, determined by the manufacturer. *ArLive* explores a new approach in which users interact with all connected objects through explicit and simple programmable behavior, transforming the multitude of decentralized applications to one unique application. To give back customization capabilities to the user, we have implemented a visual-based programming feature. This allows the link of digital life to physical objects and provides ambient notifications within their environment. This research focuses on the ability of these smart objects to communicate their functionalities in order to operate real-time modifications thanks to an Augmented Reality see-through interface. I also part deals with usage of connected devices and how *ArLive* can help us living within a connected environment.

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Augmented Reality; Internet of Things;

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Human Factors; Design; Experimentation;

INTRODUCTION
In previous years, the vision of ubiquitous computing [1] has become real. Inert objects are now interactive; they generate and transmit data as they become "alive". But interaction with these objects still requires physical actions, whether through physical triggers placed on their surface (buttons, display) or through specific physical gestures. Means of interaction are functional rather than sensible, creating a significant deficit between "soft objects" and "rough interaction". The upsurge of these connected objects in our environment generates many new interactive languages as complex interaction paradigms that users have to learn and master to fully interact with. Every remote or app to control a specific object induce a devious interaction process. In this paper, we will demonstrate how our approach and the use of Augmented Reality solves the problem of today's internet of things complexity.
We enhance user experience through Arlive, a single application aware of external context and objects capabilities. By using interaction paradigms based on Augmented Reality and real-time mapping we give the ability to the user to master invisible capabilities of his environment. In this paper, we describe a theoretical model of interaction between users, operable space and smart objects. This model is based on AR technologies which represent in this study a significant multi-modal tool for internet of things.

BACKGROUND AND RELATED WORK

From the recent spread of embedded sensors within objects, mixed reality is emerging as a popular medium [2]. Physical world, virtual world and sensor networks are operational but lack the proper inter-connections between them. The absence of interoperability in today's connected spaces establishes a substantial deficit of comprehension and acceptance of the Internet of Things from potential users. This lack also presents the problem when attempting to create global user experiences, taking into account the whole environment.

For object-embedded sensors, rather than limit usages to the functions defined by the manufacturers, we want to allow everyone to easily program his own behavior for his connected objects. This creates an opportunity for users to seamlessly control his complex connected environment. A unified and adaptive interface simplify the understanding process and would reveal the power of a seamless smart environment.

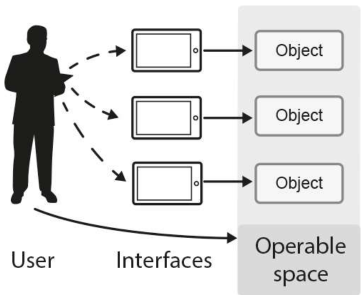

Figure 2. Current interaction with smart objects, based on the multiplication of applications. A dotted arrow represents a virtual interaction and a full arrow a physical interaction.

In the design process applied by manufacturers, each object has its own smartphone application (Figure 2). Objects are used in a heterogeneous environment because they cannot communicate with each other or be aware of the operational state of each other. We used to have static objects with functions defined by manufacturers; the design of digital objects with their set of features, the complexity of their interfaces and their means of interaction distracts users from the task they originally wanted to perform as it often appears too complex to achieve.

Augmented reality applications have been explored and applied in many fields [11] : with the democratization of mobile devices and technologies of augmented reality [12], this feature is explored in new areas, such as entertainment, advertising, art or HCI as seen on recent prototypes [4]. The manipulation through augmented reality is beneficial when the feedback is immediately visible [13]. The use of Augmented Reality (*AR*) allows the user to perform simple interactions on the objects. This feature has already been explored in HCI prototypes [3, 4] for home environment and proves usability and reliability. In exTouch [5] the AR is used as a superimposed remote to control the position of an object, giving real time feedback of the user's interaction. In these prototypes, the Augmented Realty overlay is used to perform a real-time modification of the object. The user fully controls the robot with a comprehensive feedback, however the system is not considering external factors such as Internet data or his environment, which can influence on robot's behavior.

The combination of the physical and digital world as shown in Luminar [6] demonstrates that mixing digital technology and robotics now serves as deported second display and implies new interaction technique: it merges static information from a user's computer and displays that in a non-intrusive way in his environment. An ambient notification display is what we try to produce with connected objects but only extending computer screen represents a limited usage for the context-awareness require.

Ambient notification display is an important part of our research. A notification is called *ambient* when it's not intrusive and does not disturb user action [10]. Computer technology is used today as a punctual, invisible tool. The research about displaying information into the real world started early with ambientROOM [10], which embodies the importance of interfacing digital with real world through an invisible computer to create an environment aware of virtual and physical events.

Establish a global and seamless interface for smart objects can be done by using a single application to control an entire space, who can be informed of external and internal factors. Such an interface pushes forward internet of things and user acceptance. This unexplored paradigm is researched in the prototype ArLive.

INTERACTION DESIGN

Building such an interface implies to consider the user, his needs and his environment has a whole ecosystem. Our application is centralized and behaves as a closed circuit user

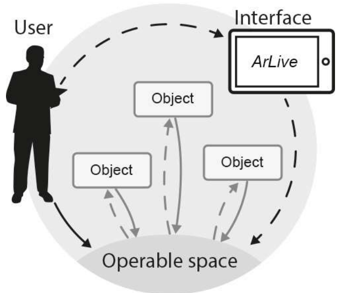

Figure 3. Our model of centralized application. A dotted arrow represents a virtual interaction and a full arrow a physical interaction.

can either operate directly with the physical space or program actions to objects through ArLive (Figure 3). In the following sections, we describe the four main characteristics that define ArLive.

A universal interface for object awareness

The aim of this project is to give the user all the tools to create custom programs. We achieved that by implementing a simple programming system, based on flow-programming paradigms [7]. In applications such IFTTT [8], the interface manages the connection of services together: in addition of this functionality, we added another layer dealing with the physical world, handling objects and user's behavior. These different "*action blocks"* are shown in the application as unified components with slightly functional variations. The objects, services or activities are displayed with a similar design and can serve as triggers or actions. In our prototype, smart objects are aware of their functionalities and push them to ArLive's server without any advance configuration needed by the user. The difference is made by ArLive between external services and objects so in our prototype, social network "bricks" allow an access to social activities (notifications, messaging) of the owner while objects allow a modification of their state.

Figure 4. Two actions programmed by a user. (*Left*) Turn off the induction charger when the phone battery is low. (Right) Change light color for each *twitter* message.

Creating behavior between social networks and objects

Smart objects obtain their full power from the data. With sensors, our physical actions are translated into digital information. An individual of the 21th century is now defined by the binding of physical and digital identity [9]. Services are no longer only virtual but related to inert objects in order to create the Internet of Things and enrich real-world experience. With ArLive, the power of this close link between objects and services is given to the user, who can create by himself some behaviors, mixing digital and physical events. Some working examples include parameter to turn on the heat when the light switch is turned on or change desk lamp color when we receive a direct message from the social network *Twitter* (Figure 4). Users can also share their customs behaviors to the community formed by other users of our service.

Display ambient notifications

By developing an ambient and pervasive notification we wanted each objects connected to ArLive are actuated in response to a specific action defined by the user. Notifications are pushed to the user only when he considers that it's important and relevant for him thus it creates a non-invasive way to stay informed. By integrating subtle cues of light, movements, or sound emits from the programmed objects, it allows the user not to adapt his environment according to his habits in terms of productivity and effectiveness.

Figure 5. Virtual AR interface added to each connected object.

Real-time state editing

The real-time modification of the object with a virtual overlay showing object's functionalities is a comprehensive way to describe capabilities which are not only defined by physical properties but can embody deeper functional layers. In ArLive, we added to each object connected to the system a virtual interface, displaying object's functions (Figure 5.). The user can interact with virtual input through this augmented reality overlay and thereby augment object capabilities and increasing customization. Allowing user to change object state in real-time with a direct visual feedback permit to merge our virtual with the physical world in a easy and understandable way.

PROTOTYPE IMPLEMENTATION

To illustrate our theoretical model we are using a restricted environment and two smart objects. We use an office room with an augmented light switch, sending is state to the App and we implemented an augmented desktop lamp. We chose these objects because they are easily augmentable robotically. With a lamp we can create an awareness and emotional robotic language, create new communication state between user and the object [14]. We are also connected to the Facebook and Twitter API, from which we can retrieve notifications.

This experimental prototype named "ArLive" is composed of three parts working together (Figure 6): a) the server, b) smart objects in the environment c) the mobile application.

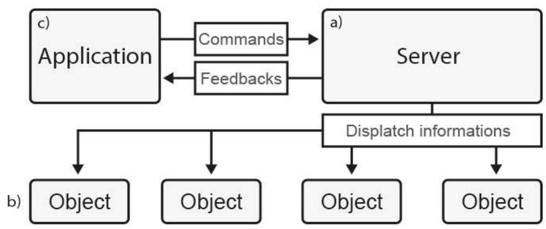

Figure 6. Implementation of ArLive: Interaction procedure in the environment.

a) The server is the central point of our augmented environment. Once connected to the Internet, the server will handle the connection to user's web services and other smart objects in the space. Data are mixed between Internet and user interactions through the mobile application, and then dispatched to the objects. In our prototype, this server is composed of software running in c# managing the database, real-time actions from the user, and performs algorithms allowing objects state modification.

b) All the smart objects are individually connected to the server, via a Arduino Yun or Raspberry pi. When objects have a layer of automation and robotic, we used an Arduino controlled.

c) The mobile application offers two functionalities. The dashboard and customization screen allows the user to access the online library of existing services, objects and actions with which he will be able to create custom behaviors. The real time modification system superimposed virtual functions to the actual object. When the user makes a virtual change on the object, this data is first sent to the server who execute an algorithm before applying an actual modification on the object.

Our prototype uses a popular image based Augmented Reality tracking system, Vuforia by Qualcomm[12]. Patterns and features in the images are recognized and stored in a local dictionary: with the help of these visual cues that the software can detect augmented objects connected to ArLive. We can create any dictionary from a single photographed image: thus with this system, every connected object can be a virtual marker and so detected by the software, regardless the manufacturer.

We have tested this prototype to a group of 20 users. 75% understood on the first try the behavior programming capabilities. Our study was focused on the use of augmented reality to understand what are the capabilities of the objects. The real-time overview of the functionalities and the modification of object aspect has been considered as a nice tool to perceive objects capacities. We let them experiment without any assistance the programming aspect of the application. Here is a selection of behaviors created by the users representative of application's modular potentiality.

- "*When I turn on the light switch the evening, send a notification to someone's phone that I'm back home".*
- *"When I receive a twitter mention to my name, move the desktop lamp to face the wall and change the color light to blue*."
- *"When I turn off the switch near the door, turn off the desktop lamp".*

These examples emerge from participant's creativity. It highlights the goal of ArLive, the mix of objects and services to embrace our whole environment in a simple user experience.

CONCLUSIONS AND FUTURE WORK

Our prototype and informal evaluation of user behavior provide us a positive feedback. We will continue by developing a new prototype, duplicable and usable in a larger context, to objectively measure the engagement of the potentials users with our system. By blending interactions modalities, our research contribute to the field of Augmented Reality and Internet of Things and helps users and designer to understand potential of mixed interactions of the user and the system on the environment.

By dealing with the private space as an information transmitting area, we opened the door to a major challenge: To keep the notion of private personal data, we need to identify users present in the same space and display information and notification only to whom it concerns. Our service should be more aware of the current context. By some machine learning algorithms, the server will be able to determine inhabitant's behaviors and be aware of the context.

The full potential will occur when we will have many augmented artifacts each with sensors, connection capabilities and motor skills. In the next couple of years smart appliances will be more present in our daily life and this design principle will become crucial to consider. To be more autonomous, we will have to consider ArLive as a global online platform, a social network between physical objects and digital services. Our platform will have a database of actions and objects directly imported from manufacturer.

To create a complete user experience, the social and sharing aspect will be also encouraged. Although the prototype actually manages the server locally, the user experience will be enhanced by providing pre-made associations between objects and services that are used by other users around the world. Our core feature lies in the simplicity of creating complex behaviors and orchestrates them by creating a dynamic link between real objects and virtual data through a unique interface fully controlled by the user. ArLive is an invitation to any user to engage in the world of internet of things by controlling intuitively their connected environment and the virtual world.

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