Smarter Objects: Using AR technology to Program Physical Objects and their Interactions

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Abstract
The Smarter Objects system explores a new method for interaction with everyday objects. The system associates a virtual object with every physical object to support an easy means of modifying the interface and the behavior of that physical object as well as its interactions with other "smarter objects". As a user points a smart phone or tablet at a physical object, an augmented reality (AR) application recognizes the object and offers an intuitive graphical interface to program the object's behavior and interactions with other objects. Once reprogrammed, the Smarter Object can then be operated with a simple tangible interface (such as knobs, buttons, etc). As such Smarter Objects combine the adaptability of digital objects with the simple tangible interface of a physical object. We have implemented several Smarter Objects and usage scenarios demonstrating the potential of this approach.

Author Keywords
Augmented Reality; Ubiquitous Computing

ACM Classification Keywords
H.5.2 User Interfaces; H.5.1 Multimedia Information Systems

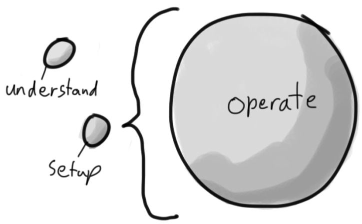

Figure 1: Understanding and setup are a small part of the overall interaction with objects.

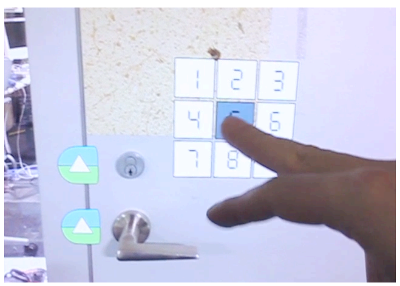

Figure 2: Using an iPad, a User operates a GUI augmented on top of a TUI in order to open a door. Green and blue tags can be seen that represent the components of a door. They can be used to connect the door's functionality with other objects.

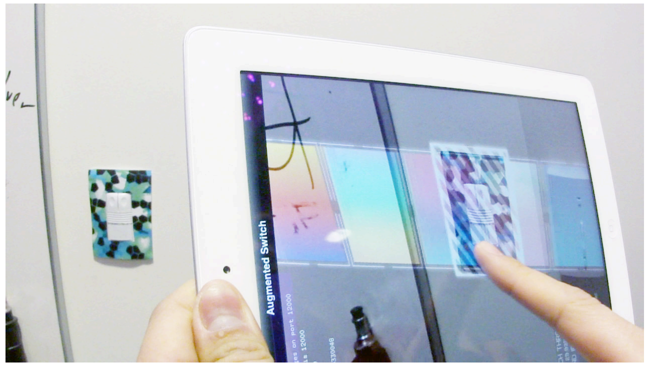

Figure 3: A graphical user interface presented on top of a tangible user interface, in this case a light switch, is used to modify the color of the room light. The tangible light switch is used to turn the light on and off.

General Terms

Design; Human Factors

Introduction

In an Internet-enabled world, objects can be constantly modified or programmed to behave in certain ways typically by means of an embedded screen with Graphical User Interface (GUI). While a GUI provides great flexibility, the use of such an interface requires the user's complete visual attention.
In contrast, interfaces found on traditional electronic products such as kitchen devices or garden tools are unable to deliver the flexible interaction that screens provide. However, these interfaces deliver continuous tactile feedback and allow the user to interact with everyday objects using muscle memory and a sense of kinesthesia. To focus on the task, full visual attention is not required. For example, a light switch can be activated even in the dark.

This paper presents a method for a seamless combination of physical and virtual interfaces that can enable every physical object to become "smarter" and provide a greater breadth of functionality, while still enabling a quick tactile interface. Such combination enables the user to balance tactile and visual awareness as well as allowing complex interactions and adaptations.

We propose Smarter Objects – a platform that allows the user to understand and program physical objects using a virtual representation through an augmented reality based GUI (see Figure 3). Once the flexible functionality of an object is understood and programmed, the object can be operated in a tactile way that requires minimal visual attention. Furthermore, such objects can share their functionality and enable interactions involving other physical or virtual objects' functionalities (see Figure 9,12,13).

Understand, Set up and Operate

There are three different interaction modes that need to be considered in order to understand the advantages of graphical and tangible user interfaces (TUI) of an object (see Figure 1).

The first thing one does when using an object is to understand its meaning and functionality. Once the object is understood, it gets customized or programmed to the user's desire. For example, one first needs to know the functionalities of a radio in order to then program its settings such as preselected radio stations. The assumption is that these steps require the most visual interaction but represent just a small amount of the full interaction with the object. The largest part of a user interaction is the daily operation.

Figure 4: Radio with its TUI represented by a tuner and a volume knob.

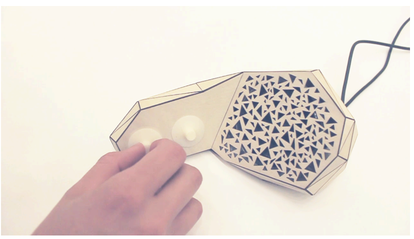

Figure 5: A user operates the tuner knob to choose from 8 tuner settings.

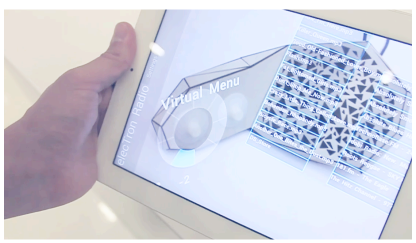

Figure 6: With an iPad a user augments a GUI on top of the TUI

This action only needs minimal visual attention, as the object is fully understood and is working as expected. This interaction is memorized in gestures, skin feeling and muscle memory. For example the radio does not require the user's visual attention.

In contrast, computer interfaces are based on visual feedback interaction rather than the tangible operation we are used to with everyday objects. For example, to turn on the radio on a smartphone, one needs to look at the display. The concept of Smarter Objects allows computation to be seamlessly incorporated into everyday objects.

Related Work

The I/O Bulbs [1] project explored how digital information and connections that exist for physical objects can be projected on top of surfaces or by mapping digital information directly into physical objects [2]. A social network for "lonely objects" [3] explored the benefits of connecting objects with each other to support the user in her or his daily decision-making. By filling the world with sensors [4] we can blur the gap between the digital world and the real world. The use of an Internet-0 [5] also enables low power local computational networks that can be connected to such sensors with the Internet or local services.

It has been shown that a real image with augmented interaction through the screen [6] can provide a better intuitive interface than an abstraction of such a system on a screen as well the usefulness of real time feedback systems through tangible interfaces [7]. Augmented interfaces have been used to remotely control electronic devices in a home-use case [8][9]. The main application of augmented reality in the area of real objects at this point is the maintenance of machines, supported by augmented in-time guidance [10][11][12].

One can say that Augmented Reality at this point is mainly focused on research to generate a better understanding of real things [13] instead of enabling the programming of the behavior and interface of the physical world objects.

Prototype examples

Some initial hardware explorations of the Smarter Objects concept include a door opener (see Figure 2), light switches with reprogrammable color (see Figure 3), and simple sensors (see Figure 11). Smarter Objects can couple the functionality of a simple tangible radio with the advantages of a graphical media player that supports all kinds of audio sources, playlists and online radios. In its daily operation, such a radio can be operated with two simple knobs (see figure 4, 5), one for tuning and one for volume. Once the music should be changed, a GUI can be used to get a better understanding of the chosen songs, the available songs and radio stations (see figure 6-8). Once a song is selected, it can be dragged and dropped on a spot on the tuning knob to reprogram that knob setting (see Figure 10). All changes on the TUI have real time influence on the GUI and vice versa.

To supply the radio with higher quality sound, it can be connected with a speaker by simply drawing a line from the radio to the speaker within the GUI (see Figure 9). Once the finger is released, the devices are connected and the speaker supports the radio sound (see Figure 12-13). A simple swipe gesture over the connecting line

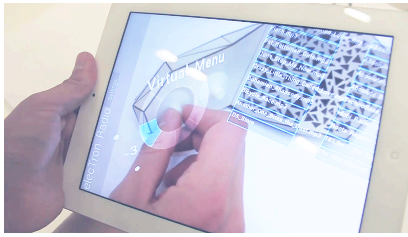

Figure 7: A user operates the TUI. His manipulations on the TUI generate changes on the GUI

Figure 8: A user operates the GUI. The user looks through the available songs and online radios.

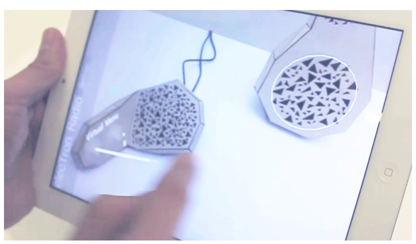

Figure 9: A user draws a line from the radio to a speaker in order to link the speaker with the radio.

cuts the connection and the devices are disconnected again. Once the settings are determined, the radio can be operated with only the TUI until the next functionality setup is required (see Figure 14).

Figure 10: The chosen song gets dragged and dropped on a spot of the tuning knob. The action overrides the previously linked song or radio at this spot.

Smarter Objects can couple all kinds of services and functions of objects. Smarter Objects have so called "tags" at the corner of their GUIs (see Figure 15). These tags are used to connect different functions of smart objects. The interconnection occurs by touching a tag on the GUI of one smart object and dragging it to the tag of another smart object. For example the volume knop of a radio could be connected with the blending functionality of a blender. A line representing this connection is drawn between the two tags. For example, the slider functionality of a toaster can be connected with the speaker of an alarm clock in such a way that if the toaster is ready the alarm clock rings.

In addition to connections between smart objects, logical virtual objects can be placed in the GUI space as

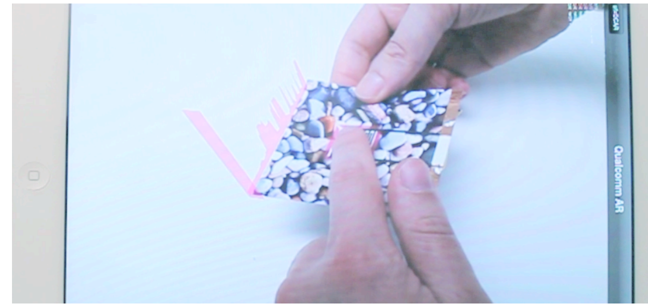

Figure 11: A working prototype, whereby a user touches a capacitive sensor and the sensor data is visualized on the sensor in real-time by the use of an iPad.

well through the use of data flow programming (see Figure 16). For example a virtual clock object can signal the coffee machine to turn on or a new Facebook message can switch the light on.

The Smarter Objects concept can be used to set up and understand devices that are too small to support different physical affordances or show all functionalities on its surface. For example, devices that one wears on the body like watches, jewelry and wristbands. The setup of such devices is complicated, as they lack enough space for buttons and screens. By avoiding complex functionality on the device, small ultra low power devices can be built that still provide the capacity for complex functionality. For example, a simple sensor can collect environmental data and visualize all its data through the use of a superimposed GUI (see Figure 11). In such cases, the Smarter Objects interface can be used to increase the interface space of such objects. Once the device is set up with relations, macros and programs, it can be used to one's desire with a minimal interface.

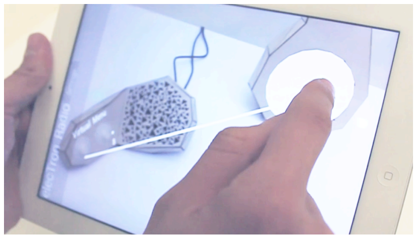

Figure 12: Once the line is drawn and the finger released, the devices are linked.

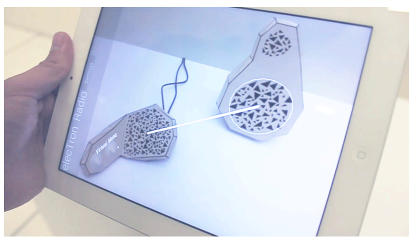

Figure 13: The speaker plays now the radio music. The line can be cut with a swipe gesture to unlink the devices.

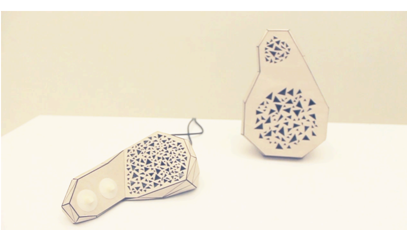

Figure 14: Speaker with Radio are now programmed with a GUI.

Implementation

The TUI and the GUI are tied together through a server system. All changes on the TUI have real time influence on the GUI and vice versa. Whenever an action is performed at one of the interfaces a message get sent to the server. The server then sends it to the other interface in order to synchronize the states. The augmented GUI is realized with the Qualcomm Vuforia framework [14] that can use any image as a marker and project a 3D scene on top if it. The GUI is programmed with open frameworks. The Touch Device running the GUI is connected with the server via WIFI and the software uses the Open Sound Control protocol (OSC) to communicate with the server. The physical representation of the Smarter Object uses a WiFly RN-131 Wifi module and an Atmega32U4 microprocessor to send the TUI data via the OSC protocol to the server. As all TUI components basically consist of sliders, push buttons and rotation knobs, the system is engineered to be flexible enough that any object with electronic components can become a part of the interaction.

Usage Scenarios

Kitchen

In the kitchen, Smarter Objects can help to operate devices needed for following a recipe. This means one can place a pan in the oven and select an oven setting that has been used before. A mixer can have the perfect setting for the loved smoothie but only a simple push button needs to be activated in order to start the preprogrammed setting. The microwave can be set up once with a beautiful and simple graphical user interface that explains all functionalities or even provides recommendations.

Car

In the car, Smarter Objects can help to individually customize the functionality of the steering wheel, the temperature range or the functionality of the radio. This means less tangible interfaces need to be placed in the car and all interfaces still remain customizable.

Entertainment

In the entertainment area, a Smarter Object can be used to simplify the set up of TVs and Set-Top-Boxes using a graphical user interface. Since the user of a TV wants to keep the eyes on the screen, a tangible remote can be programmed using the augmented GUI. Services, complex tasks and macros can be added to the tangible keys, so that the experience of operating a TV becomes more intuitive. Smarter Objects can also be used to simplify the connections between different media devices by making them virtual and customizable.

Garden Tools

Smarter Objects can help to check gas levels on lawnmowers or set up parameters for the blade speed as well specific patterns. Later this functionality can be accessed using a simple rotation knob on the lawnmower. Drilling machines can be set up without a deep understanding of the task. A user can set up the material to drill in the graphical interface that also tells him how to operate this setup in the right way.

Industry

In a production plant, Smarter Objects can help plan and program production processes directly connected to tangible interfaces used in such productions. The settings and reference data for such processes can be programmed using the graphical interface without any

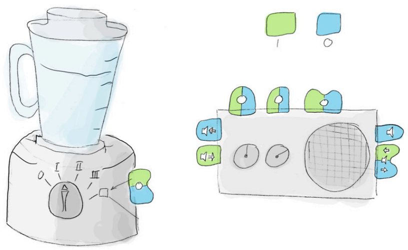

Figure 15: A Sketch to illustrate Tags that are shown in a graphical user interface augmented on top of a physical object. These tags are used to program the connections between Smarter Objects.

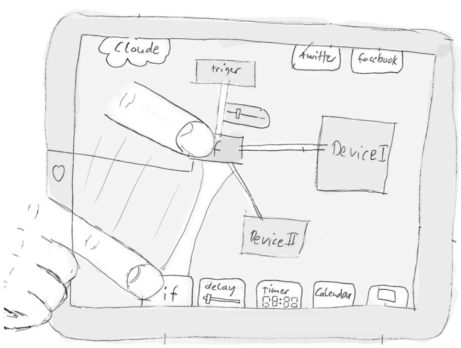

Figure 16: A Sketch to illustrate a Data-Flow-Programming environment augmented in to physical space in order to program the behavior of smarter objects.

additional screens on the tools. Later, those tools and interfaces operate according to the setup preferences.

Future scenarios

The Smarter Objects system can be used with any device that can act as a visual input and output device. This means that instead of using see-through AR technology available on today's tablets and smart phones we could also use transparent displays, rooms that use technology like the cave, augmented reality glasses like Google Glass or the projected AR devices envisioned in the MIT Fluid Interfaces Group [15]. Devices that do not have a touch interface may act as direct manipulation interfaces, whereby the augmented interface is controlled on the surface of the physical object. Connected to the Internet, a user could share ownership of Smarter Objects with other people and create a social network of objects. Such a network will generate timelines for all connected objects as well as track their usage and their connections to other objects. By sharing ownership, a user can share information to teach and learn about objects.

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