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A Design Model for Tangible Interaction: Case Study in Waste Sorting

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Abstract: In this paper, we propose a design model for applications with Tangible User Interfaces (TUI). This model aims to support designers in organizing the different elements and their relationships. We then implement the model through the design of a Serious Game for an RFID tabletop that uses tangible objects: this Serious Game simulates microbiological waste sorting in a practical educational setting. In this case study, a scenario is described, highlighting the use of the design model. The conclusions and suggestions for future research are then presented.

Keywords: TUI Design Model; Tabletop; Tangible object; Serious Game; RFID; Waste sorting

1. INTRODUCTION

Shneiderman (1983) says the following about video games: "perhaps the most exciting, well-engineered - certainly, the most successful - application of direct manipulation is in the world of video games". With improvements in technology, inputs and outputs are getting closer, enhancing the feeling of direct manipulation (e.g. touch, stylus, movements). One of the emerging technologies that fosters this enhanced closeness involves Tangible User Interfaces (TUIs) (Ishii & Ullmer, 1997). TUIs allow interaction to take place with a virtual application through real objects that can represent application data (see the definition of (Hornecker, 2005)). And finally, to become closer, inputs and outputs have merged (Ullmer & Ishii, 2000).

In the video games field, we can refer to *Activision Skylanders* released in 2011. In this game, one or more real figurines are selected and placed on a base. A playable avatar of one or more figurines appears in the virtual world via the TV screen. We can also mention the STARS platform (Magerkurth et al., 2004) to generate games for tangible and tactile tabletops. This platform aims to emulate board games, enhancing them by adding a virtual layer (sound, a screen-based game board equivalent, a vertical screen for general data and Personal Digital Assistants for private data). In this case, a player directly interacts with a figurine and moves it.

The question that subsequently arises is: how to design a TUI application taking into account every physical or digital element? In order to clarify this point, we propose in this paper a design model which takes into account the different elements we can find with TUI as well as their relationships.

After identifying what kind of video toys considered as TUIs exist on the market, we will present several HCI models in Section 2. From these models, we propose a design model for tangible interaction described in Section 3. A case study showing the development of a Serious Game on a TUI is then presented in Section 4. The implementation of the serious game is presented in Section 5 in a scenario illustrating the model. The article ends with a conclusion and suggestions for future research.

2. STATE OF THE ART

To begin our study, we first considered video toys currently available on the video game market; they are for us a source of ideas for designing new types of industrial or educative applications. We then studied several HCI models that could be compared with each other to create a model for designing TUI applications.

2.1 Video Toys as Tangible Objects

By video toy we mean one or more physical elements, such as figurines, linked to at least one digital application. This link augments the figurine, giving it a life, capacities, and so on.

Activision launched the first successful toy of this kind in 2011. It is Skylanders: Spyro's Adventure game. The digital character you play corresponds to the physical figurine placed on the base and linked to the game console. Similarly, in 2013 Pokemon Rumble U by Ambrella uses the NFC component of the Wii U game console to incorporate figurines. Placing a Pokemon figurine on the GamePad allows the player to use this Pokemon in the game. The Pokemon and Skylanders figurine characteristics, which evolve throughout the game, are stored in the figurines. A similar game released by Avalanche Software in 2013 is Disney Infinity. It uses trophy and disc objects to enhance the current character's abilities. These discs can be superimposed and the character figurine can be placed on top. More recently, we can cite Nintendo Amiibo figurines which are available since late 2014. All these physical toys are physical avatars, behaving like an ID card. Once a figurine is placed

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on the base, users no longer need to interact with them and can play using pads and screens.

Prodigy by Hanakai Studio is a game developed in 2015. It works with figurines, a base and cards. The base is linked to a computer. It is a tactical game. Contrary to previous games, in this one, players interact with physical elements. The users can strategically place their figurines in different squares on the base. Putting a card on the base allows a figurine to perform a specific action that will be digitally represented (through the screen). Here, the digital layer augments the real situation, adding a fantasy layer to the game and making the characters seem alive. On tablet (iPad), the version of Cars 2 developed by Avalanche Software in 2011 allows controlling a physical small car called appMATES, while the screen of the iPad displays the landscape for the race. The car is placed directly on the iPad and allows the user to control the direction taken. Thus, the object is directly immersed in the virtual world. Finally, the ePawn company (2010) was able to develop video toys using its Arena surface (2012) and tracking technology. As for the Cars 2 iPad application, physical elements are detected and immersed. Several elements can be detected at the same time, and mobile elements can even be linked to the surface.

By analyzing these games, we can observe three ways of using a digital layer with physical objects: (1) A physical object enables an avatar with associated stored data to be selected. Then, all happens digitally. (2) The physical object is used to play. But to endow it with a life, movement, abilities and things that cannot be provided physically (or in a very complex way), a digital layer is used. This layer augments the object, or the image we have of it. (3) The physical object is immersed in a digital environment. One would not function without the other. The digital layer brings meaning to the game (for example, the road and obstacles), and the physical elements must respect this meaning. More than augmenting the object with effects, the digital part forms the structure. This notion of structure can be applied to a set of objects as in Disney Infinity application. The discs, alone, don't have any sense. But with a figurine, it increases one of its ability. The figure is a part of structure for the disc.

This section deals with objects that represent the targeted element with which the user wants to interact. But sometimes, objects in augmented reality are tools, intermediaries between the user and the targeted object. This is what is explained in the next section.

2.2 Domain Object and Interaction Instrument

Beaudouin-Lafon (2000) says that "Our interaction with the physical world is governed by our use of tools". He defines then what he calls domain objects and interaction instruments. The domain objects are directly linked to the aim of the task; they are "objects of interest", whereas interaction instruments are intermediaries used to perform the task and to interact with the objects of interest.

The AppMATES car from the Cars 2 application is a domain object, as it is the object of interest in this racing game. In contrast, the application introduced by Fitzmaurice et al. (1995) uses tangible bricks to manipulate digital forms. In this case, the bricks are interaction instruments. If we refer to Ishii and Ullmer works (2012), we can tell that physical domain objects are linked to digital information and physical interaction instruments are linked to computational function.

Beaudouin-Lafon stipulates that depending on the task to be performed and the user's focus, an interaction instrument can turn into a domain object. He gives the example of a pencil, which is actually an instrument for writing text. The pencil becomes an object of interest when the user needs to sharpen it; the pencil sharpener is the interaction instrument.

To go further in the analysis of the relation between the physical and the digital layers, we refer to the notion of feedback: how a user can glean information from his/her experience through digital and physical interactions.

2.3 Tangible User Interfaces and Feedback

Ishii and Ullmer (2012) explain that three feedback loops exist in this field. The first loop involves immediate tactile feedback received by the user when he/she manipulates an object. It is a passive feedback felt by the user, for example, when moving the object, changing its direction or putting it on the table. This feedback allows the user to note the new state of the object through his/her haptic perception. The second feedback loop pertains to what the user perceives from the digital device. The system's state is updated according to the new state of the object(s); this update is directly communicated to the user through digital information (the feedback could be visual or audio). It concerns all non-tactile feedback. The third kind of feedback loop involves an updating of the object without user intervention. In the model presented in (Ishii & Ullmer, 2012), the computer actuates the object (the object can then modify its appearance or move by itself). For example, we observe that, in this era of smart objects, the object can update itself with contextual changes.

Thus, there are three feedback loops to take into account when designing a TUI application: (1) sensory feedback linked to the object, (2) digital feedback linked to the application and (3) actuation feedback of the object by itself or by the application. The two first loops are the loops experienced most frequently when using TUIs. They are even considered as essential In Ishii's and Ullmer's opinion in Tangible Interaction.

2.4 The Execution and the Evaluation Phases

We can refer to the Norman's action cycle (Norman, 2002) to understand when the previously studied feedback loops can be exploited.

There are four elements to consider in Norman's model: (1) the goal of the user, (2) the execution phase (i.e., what the user does to achieve his/her goal), (3) the world and (4) the evaluation phase (i.e., when the user perceives the world and compares it to his/her expectations). The execution phase is divided into three stages: (1) the intention (by what means