Tangibility and human-computer interaction: an alternative approach to affordance

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Abstract - This article deals with a tangible interface, Tangisense, and aims to present the contribution of tangibility to the man-machine interaction from the point of view of affordance. Some experiments build on a tangible table Tangisense, developed by the laboratory, demonstrate that the affordance plays different roles related to the context, the type of task and the collaborative interaction with others users. We show that the affordance of objects is a complex concept that depends not only on the appearance of the object but also on what the users do in collaborative context.

Keywords: Tangibility, Interactive table, Affordance, Collaborative work

I. INTRODUCTION

For 25 years, tangible interfaces (TUI = Tangible User Interfaces) are spreading more and more (Blackwell et al., 2007), so that it could eventually replace the traditional graphical user interface of applications such as games, participatory design work, the mock-up design, etc.. (Kubicki et al., 2009a). The definition by Ishii and Ullmer (1997) is very concise but easily understandable: it comes to manipulating real objects that are integrated in a virtual environment and have digital capability of interaction - it is not so just to interact with virtual objects on a screen but more interacting directly by and on such objects. Thus, the TUI allow to not insert an artifact of communication in the sensorimotor process that is established between the user and the environment or to break the continuity of touch created by the mouse as in graphical user interfaces (Moggridge, 2006). Items used here are physical but embedded with digital interaction capabilities (Blackwell et al., 2007) somehow they are "augmented". In other words, everything happens as if the "digital information became palpable by hand directly perceptible by our peripheral senses" (Ishii et al., 2001).

In this type of tangible interface, the object is both a tool of the interface, object of the application and device for the interaction, which raises its ambivalent status. Further interaction is spatial and takes place in real space: users can move in this space to interact. Unlike the interaction with a computer screen where the user must manipulate the mouse, tangible interfaces require different postures for the body. Indeed, objects and space introduce constraints to the behaviors and relationship for the users each to others: the agent is in this case literally in the physical world and metaphorically in the digital world. This therefore defines the postures that allow, restrict or command behaviors. Finally, the representations are outsourced; the feedback may be visual, tactile or haptic (Hornecker and Buur, 2006).

In this paper, we examine the tangibility in terms of affordance and collaborative work from experiments with the interactive table Tangisense, exploiting the RF-ID technology (Radio Frequency Identification) and allowing collective interactions with tangible and virtual objects.

II. THE TANGISENSE TABLE

Figure 1 shows the interactive table (Kubicki et al., 2009b). It is like a magnetic retina, able to detect and locate RFID tags pasted on various objects. The table consists in 25 blocks, each containing 64 antennas (8 x 8) by 2.5 cm square on a surface of 1m2. Each block contains a processor reading RFID antennas, an antenna multiplexer and a communication processor. The blocks are linked together by a control interface connected to the host computer by an Ethernet bus.

A General Characteristics

With this technology, one can recognize tags for objects superimposed each on other and their positions in the workspace. One can detect an object completely hidden under another bigger than himself, and find its position too. Each tag has a few memory for storing information in the RFID. The response time obtained with Ethernet communications and RFID device-reader provides speed performance compatible with the speed of a human gesture. The simultaneous movement of a block of 64 RFID tags is detected in less than one second, implying a possible detection of more than 60 moving objects at once. The algorithms embedded in the table offer search strategies, aggregation and exchange between the RFID tags allowing a global processing in real time. The main novelty of the table likes in the density of the antennas which allows a compatible spatial and temporal resolution with the real-time detection of objects in movement. So she can be used as a non-specialized tangible human-machine interface.

Figure 1: The Tangisense table under a configuration of musical creation. Bright areas (LEDs in the table) are activated by tangible "characters". A cube in the foreground is a musical instrument; a CD in the background is a database of sounds that can "dump" on the table.

B The table objects

There are two different types of objects on the table that can be interactors: (a) the virtual objects (as in a GUI, such as scroll, buttons, etc...) and (b) tangible. The virtual objects are projected onto the table using an LCD situated on the surface of the table or a video projector placed vertically above the table (Fig. 2). Tangible objects are equipped with RFID tags glued to their base. In these tags, it is possible to store information such as a last movement, name of its owner, etc...

Figure 2: The Tangisense table used in a road traffic simulation application. One distinguishes tangible objects (e.g. road signals) and virtual objects video-projected (e.g. roads).

Several applications have been programmed for the table. In addition to a road traffic simulation (Fig. 2) two applications were referred to the musical production:

(a) Automaton Music: this is a software for interacting with instruments (tambourine, drums, horn, etc.). To do this you must first lay on the table a figure corresponding to a particular rhythm, when installed, the LEDs will light up on the table. When an instrument is placed at the same time that the LED lights up when it hears the corresponding sound: drums or whatever. In this application, the rhythm has been set with reference to the game of life and metaphorical Gardner-genetic with the laws of the cells (a led = a cell). Programming has been done by simulating the life of cells.

(b) CD Judbox: the principle is similar to the foregoing; the difference is that they are not instruments but textures. The application is to make an audio CD on the table and you can then extract various textures and then you can be recovered through these transparent cubes and replay them at will. As indicated above you must first file a character to the rhythm so that the LEDs are lit and the sound is played accordingly.

These are the objects of these music applications we consider in the following.

III. Interaction, posture, collective work

Interacting with a tangible interface does not have the same conditions as traditional GUI and thus generates a particular interaction. Indeed, this kind of technology allows the user to have an experience more "natural" and "friendly". Indeed, according to (Ishii et al., 2001), this interface would give the feeling of being connected to the real world and so it's more successful biofeedback. Through the multisensory control that allows direct manipulation of objects, we have the opportunity to have richer expressive gestures that allow natural and intuitive interaction (Fiebrink and Morris, 2009). In addition, tangible interfaces offer the opportunity for users to perform optimally with direct manipulation interface. They can touch the item they want to handle; the body is then used to control the interaction (Schneiderman, 1983). In addition, users can change the location of objects at once from them but also against other users, consequently it can be attributed to a significant place and thus develop a spatial reasoning (Manches et al., 2009). The advantages with this technology are manifold. Interaction with both hands is strongly encouraged, which is important because the physical capabilities of the hand and wrist are also rich (Fitzmaurice et al., 1995). On the other hand, users can be placed anywhere around the table, entries are spatially and it significantly improves the ability to communicate with the computer. Physical artifacts facilitate interaction by making more direct interface, and especially more manipulable. This type of technology also encourages the collaboration of several people (Fitzmaurice and Buxton, 1997). And finally, since the objects are manipulated in three dimensions on a horizontal surface, the vast majority of these tables offer a generous workspace and allow the user to act while talking and keeping an eye on what others do (Manches et al., 2009). Moreover, one of the key points in this interaction remains, according to the authors, the visibility of other users and therefore often the goal of understanding and gesture (Fiebrink and Morris, 2009). However, some disadvantages are: given that the individual is interacting with an interface that can be shared with several people, some studies have shown that people have fear to have a physical collision or that of encroach on the territory of a neighbor. The difficulty in reaching objects out of reach was also discussed (Fiebrink and Morris, 2009). The very nature of the human body means that there are constraints in terms of natural positions, the environment in which is the interface will thus influence the actions and limit certain movements which are then obstacles (Benford et al. 2003). In summary, despite these drawbacks, tangible interfaces restore a significant role in manipulating and exploiting the dexterity acquired by humans in their daily environment (Couture et al., 2007). The ability to let subjects freely interact with objects by touching them and moving them directly constitutes the heart of this particular interaction. The interface improves multiplayer action allowing better hand coordination, parallel actions, a better perception of space and changes in perspective by the possible moves around the table.

IV. The Affordance

Gibson introduced the concept of affordance in 1979 and made it a theoretical pillar of the ecological approach. The affordance is initially so that the object allows the individual to do in a situation such as the subject perceives, so it is perceived by an individual with an object and possible actions that item proposes. This concept has produced numerous appropriations by different authors, especially by Norman. According to Norman's, affordance corresponds to information needed in the world to act appropriately according to the project and the objectives of the concerned actor - the appearance of the devices must therefore be able to provide evidence relevant to proper use through their affordances, perceived and real part of a second. (Norman, 1999). Mucchielli (2000) uses the term "holders of proposed interaction" to refer to objects affordances that have property to offer some plausibility of their duties. Allaire (2006) went further in speaking of "friendly" to name the object that makes visible its usefulness in context and leads the individual to act. With this in mind it is important that objects have a tangible interface affordance. Indeed, with this type of technology, tangible objects are perceived only through their assigned functions, the principle of affordance is then forgotten: how a stone tabletop music could acquire it and the role of his or rhythm?

In summary we can conclude that the affordance is a relationship established between the user and the objects in the environment through their properties but also according to the task to perform and in relation with others agents acting with these objects. The affordance problem has three dimensions: purpose, task, people group.

V. Experiment

To understand this concept of affordance, an experiment was conducted in our laboratory (Becker, 2010) to measure the affordance of objects in a work situation with the interactive table TangiSense. The subjects were alone and had to perform a task with objects more or less affordable that they did not know (a situation called direct) or had to perform these tasks with other people who knew and manipulating objects (situation called indirect).

A Assumptions

The theoretical assumptions are:

- H1 – There is some differences in understanding between objects affordable or not, regardless of the situation and players (in other words, the affordance depends essentially on the nature of objects),

- H2 - The situation of interaction of an object affects its understanding and construction of affordance, in particular by the presence of other agents,

- H3 - The single or multi-functionality of an object affects its understanding and construction of affordance (the multi-functionality of an object is defined by the fact that it has a self affordance and an inherited affordance increased by its digital capabilities – for instance a glass with an interactive function serves still to drink).

The operating assumptions are that these differences are measurable in terms of understanding time (as soon as objects are perceived by the user until he describes its functions) and ease of comprehension (number of errors in the subjective assessment of the task).

Other assumptions in addition to these main hypotheses, since in an HMI (Human Machine Interface) are generally divided between several types of objects schematically: (a) the objects of the interface (menus, scroll bars, etc...) common to all applications and (b) the objects of the application (icons, functional objects, dialogue box, etc...) specific to one application. Thus it is expected that:

- H '1 – For a degree of affordance equal, the interface objects will be understood more easily and faster than the application objects, because of their cultural' largest value (indeed the people have acquired this culture of interface objects from recent and frequent use of the GUI),

- H'2 - The most affordable interface objects are the more transportable to other applications as objects not affordable of the interface (under the condition they keep their functions), but conversely they are less interchangeable in terms of functionality,

- H'3 - The less affordable objects of the application (and therefore less meaningful) will be a part of the most versatile and also the most customizable and appropriated by an user.

B Experimental protocol

The design of the objects was made in participatory design sessions with musicians, designers and ordinary people. They were instructed to draw affordable objects for music applications described above (Fig. 3 provides a sample output). Their results were validated by all participants.

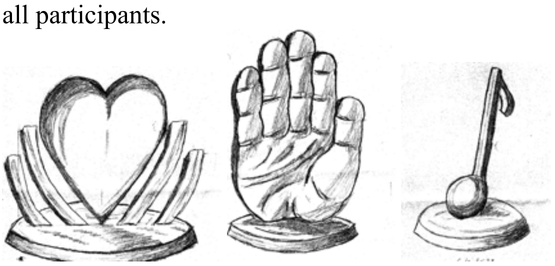

Figure 3: Object "rhythm" (heart shape), object "off" (hand-shaped) and object "note".

The interface objects were selected *a priori* from the "culture" induced by the graphical interfaces, like an eraser to erase, "stop" to stop "cursor" to the rhythm, etc...

We will not describe in detail the design sessions that led to realize the matching items that were used in the remainder of the experiment. We took 16 subjects divided into 2 groups each competing to test each hypothesis, for example H1 task was to understand the function of objects in various situations, for some objects were selected from more affordances for others among the fewer affordances. And so on for H2, H3, and H'1 H'2. Time measurements and understanding of the number of errors were made, complemented by interviews after the session with a questionnaire using Likert scales.

VI. RESULTS

We present a table of results in Fig. 4.

Results depending on the situation	Direct		Indirect	
	Obj. aff.	Obj. non aff.	Obj. aff.	Obj. non aff.
Task difficulty (Lickert 1-6)	1, 0	1, 0	1, 0	3, 0.925
Understanding difficulty (Lickert 1-6)	2, 0.5	3.5, 1.58	3.25, 1.6	3, 0.925
Understanding duration	10.5, 4.3	35.8, 24.2	36.3, 9.3	23.5, 11.4
Number of errors before validating	0.125, 0.3	1.1, 0.4	0.375, 0.5	0.6, 0.5
Number of errors	0.125, 0.3	0.375, 0.5	0.25, 0.4	0.6, 0.5
Subjective estimation of the affordance (Lickert 1-6)	1.6, 0.3	5.5, 0.2	5.5, 0.1	6, 0

Figure 4: Results of measurements validated by questionnaires. The values in each cell are mean and standard deviation for all subjects who passed the test.

On this table we can read that: in "direct situation" affordable objects are most relevant to the task (compare columns 1 and 2), H1 is verified, but not in "indirect situation" (comparing columns 3 and 4). Moreover, for an affordable object the "direct situation" is more favorable to the comprehension (compare columns 1 and 3) and less favorable for the "indirect situation" (comparing columns 2 and 4). H2 is verified. Everything happens as if there were an affordance "for itself" (egocentric) and affordance "for others" (exocentric). A closer analysis shows that other cues than the appearance can allow decoding the functions of not affordable objects (auditory cues, effects of their actions in the task, socio-cultural inferences). As a corollary analysis also shows that H3 is validated, more precisely: if an object is multifunctional, it will be harder to understand but at the same time, richer for the interaction.

Fig. 5 shows other aspects of affordance in relation to the type of objects (application object / interface object)

Results depending of the type of the objet	Application objet		Interface objet	
	Obj. aff.	Obj. non aff.	Obj. aff.	Obj. non aff.
Task difficulty (Lickert 1-6)	1.75, 0.4	2.125, 0.8	1, 0	3, 0.925
Understanding difficulty (Lickert 1-6)	3, 1.8	3.5, 2	2, 0.8	3, 0.925
Relevance for reusing the function in other context	2.75, 2	3.875, 1.4	1.75, 0.8	1.8, 1.4

Relevance for reusing the object in other context	2.625, 1.9	4, 2	6.75, 0.4	3.25, 1.4
Understanding duration	70.6, 37.9	58, 32.3	10.5, 9.3	23.5, 11.4
Number of errors before validating	0.5, 0.5	0.75, 1	0.375, 0.5	0.6, 0.5
Number of errors	0, 0	0.125, 0.3	0.25, 0.4	0.6, 0.5
Subjective estimation of the affordance (Lickert 1-6)	2.1, 0.8	6.5, 0.5	1.6, 0.3	5.5, 0.2

Figure 5: Results of measurements validated by questionnaires. The values in each cell are mean and standard deviation for all subjects who participated to the experiment.

A detailed reading of this table shows that the assumptions H'1, H’2 and H'3 are validated.

VII. Discussion

The above results must be read with the usual precautions:

a) The study is limited to a particular table and specific applications,

b) The number of subjects of the experiment is small and does not cover all socio-cultural categories,

c) The conditions are not entirely ecological.

Despite these restrictions strong trends emerge due to the particularities of these objects "augmented": for one hand the multi-functionality appears in these objects is more difficult to grasp and understand for the subjects and for another hand the question of "technological culture" raises other forms of affordance. Finally the collaborative work seems to promote knowledge transfer and co-construction of meaning through some affordance we called exocentric.

VIII. Conclusion

The affordance of an object improves egocentric understanding of the task but it is not the only cause, there is also strong enough and the situation of collective work - that is to say what others do also with these objects. The collective work improves the understanding of non affordable objects in the task. On the other hand affordance takes other signification for technological "augmented" objects for tangible interfaces: multi-functional aspect in part makes these objects more difficult to understand but at the same time easier to "transport" in other applications, maintaining their functional inheritance.

Socio-cultural issues are thus rose which bind to the affordance reuse and appropriation of objects: the more a function is "hidden" the more is “my own”.

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X. Bibliogrqphy

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