Study of Tangible User Interface for handling tridimensionnal Objects.

Ludovic Garreau
LIPSI - ESTIA
Technopole Izarbel
64210 Bidart, France
l.garreau@estia.fr

Nadine Couture
LIPSI - ESTIA
Technopole Izarbel
64210 Bidart, France
n.couture@estia.fr

ABSTRACT
The field of interaction system is very wide from the mouse to the data glove while in passing by the cubic mouse [7], metaphors ("WIM" [17], voodoo Dolls[13]) and tangible user interface. In these systems of interaction, the designer of these interfaces seek to simplify the interaction by using human knowledge in order to create behavioral interface. In this paper we propose a new kind of tangible interface based on the handling of physical object that we call "interacteurs". In that goal, after a short introduction on the context of the study, we introduce the concept of Tangible User Interface with samples. Then we present our reflexion on TUI for Handling : from the hardware to the software. For that, we define a typology of interacteurs based on concepts proposed in Design For assembly (DFA) methods, and we explain our idea of a tangible user interface: ESKUA.

Keywords
Computer Human Interaction, Tangible User Interface, Interacteur, Handling, Visualization.

1. INTRODUCTION
The scientific community generally agrees that traditional input devices, mouse and keyboard, are limited and that it is necessary to create new devices, in particular when three-dimensional (called 3D in following) scenes are to be visualized. New Human Computer Interaction systems have appeared, proposing new concepts for hardware (input and output devices) well as for software (graphical interfaces). With those systems, authors don't search only to create new hardware or software, but want to propose new manners to interact with virtual objects.
Historically, the first systems of interaction between human and the computers are at the beginning of the years 1960. One of the first was the Sketchpad (Sutherland, 1963) the purpose of which was to make it possible to the user to interact in a direct way with the software interface using an optical pen. This system, like the current systems "mouse and keyboard" are clearly limited by the interface of visualization, the screen, and by a space of interaction in two dimensions. The traditional devices evolved logically towards the systems of 3D mouse and joystick which pains to be essential because their uses creates a considerable cognitive difference between the action carried out on the mouse by the user and the result in the 3D numerical scene. To palliate these disadvantages, two currents emerged: virtual Reality, Mixed Reality (Head Mount Data, panoramic screen, Workbench) and the tangible user interface (cf. 2) (Aish, 1967) quoted in [4].
As Fuchs [8], we think that the systems directed towards visualization, often gathered by the term of "Virtual Reality", require complex haptic interfaces in their realization for an interaction of quality with the digital model. Ware and Rose [23] showed that the use of real objects, included in tangible user interface, clearly improves the performances of the users at the time of the phases of handling of virtual objects.
We propose a tangible user interface which enable to have a physical perception of the data constraints during the "virtual" phase of combination and handling by the use of special physical icons that we call *interacteurs* (cf 3.1).

This paper was presented at "Physical Interaction (PI03) - Workshop on Real World User Interfaces", a workshop at the Mobile HCI Conference 2003 in Udine (Italy). September 8, 2003.

2. THE TANGIBLE USER INTERFACE
Ullmer and Ishii in [21] define system based on the real object as a **T**angible **U**ser **I**nterface (called **TUI** in following) by analogy with a **G**raphical **U**ser **I**nterface (usually called **GUI**) (cf. figure 1). Ullmer and Ishii describe the TUI like a physical realization of the graphical user interface (GUI).

2.1 Description
TUIs (Latin tangere: the capability to be touched) seek to make intuitive interfaces whose finality is to couple the physical reality and the numerical one in order to simplify interaction. TUIs are based on the use of real objects which allow a representation of the data and a physical control of numerical information [19].
So by joining the idea developed in [19], we think that the TUIs can be one more in the combination and visualization of several virtual objects. With the real objects, handling is simple to realize but nevertheless brings to identify the difficulties of combination concerning the questions of sym-

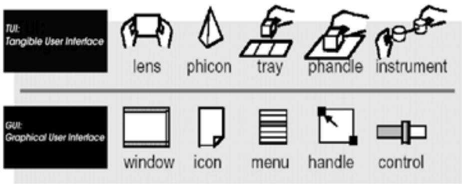

Figure 1: Analogy between GUI and TUI
(reproduce from [18])

metry, occlusions, and setting in position of the parts (cf 3.1). Moreover, it is now admitted [23], [11] that the use of real objects for displacements and the control of the virtual objects is more powerful than the traditional systems (Virtual Reality, 3D mouse).

2.2 TUI for handling

A TUI is made up mainly of two parts: the tangible part (to allow the interaction) and the visualization part (the feedback of handling). The realization of TUIs consists in using tangible objects (cubic, plane, etc.) who have a true and figurative meaning from their forms and their colors in the real world. The tangible object positions and orientations are captured by the way of sensors or by the use of camera(s) and then transmitted to the computer. To name the tangible part, Ernst, Schfer and Bruns [6] use the term *graspable* and Ullmer et al. [20] reference the words *"Artifact, Container, Tangible, Object, Phicons, Objects, props"*. We choose as Ullmer and Ishii in [18] to use the term "artifact" to designate physical objects in TUI. The artifacts are at the same time an input device and an output device. They symbolize the concept, and provide control of the virtual data. So, there are as much artifact as different data and control, for example the luminous room [22], the metadesk [18] and Ernst's TUI [6]. The handling of the artifacts modifies the virtual objects (input device), moreover only by casted one's eye over the artifacts, contrary to a 3D mouse, provide information to the user (position, orientation, etc.) on the virtual objects (output device). In [22], authors says "The students and professionals who have experimented with it (authors' note : The luminous Room) affirm that its direct manipulation style -"like working with real thing"- both fosters and takes advantage of the spatial understanding inherent to work with real optics".

The user is not "attracted" by a feedback different than output device (for example : screen). The consequence of this was that the user gathers his thought on the action and doesn't search the result on an another device. Anderson et al. (figure 2, [1]) illustrate the idea that the application and the computer are only one successive stage with the combination of artifact.
To be closer to our domain, in the next part we study TUI created and usable for handling.

2.3 Samples of TUI

We describe components of TUI and discuss about specific application. The main difficulty is to find the good artifact which allows convinient handling and symbolizes a right representation of the manipulated data. The closest related works are the system developed at MERL[1] Laboratory [1] and the "Active Cubes" [10].

2.3.1 *Application of Merl*

An application developed within the laboratory of Mitsubishi is based on the principle of combination of part (figure 2). In [1], they present *physical modules which describe, interpret and decorate the structures in which they are assembled* . Here, the *containers* are blocks of style LEGO^{TM} which determine and communicate their own *structure* with a computer once the finished combination. A software based on rules interprets these *structures* like a construction (building), analyzes their architectural devices, then adds the geometrical details and the decorative elements (for example: texture). The recovery of the geometry 3D is then reduced to the problem to determine the identity and the connection of the blocks and to communicate this information with a principal computer. The three principal problems are : the connection, communication and the duration of the estimation of the geometry.

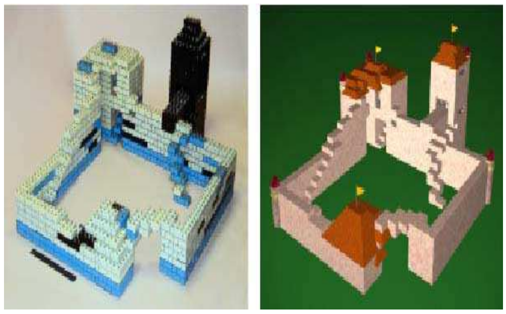

Figure 2: Merl project
(reproduce from [1])

2.3.2 *ActiveCube*

The "Cognitive Cubes" [16] is describe by this author like an application of ActiveCube, a Lego^{TM}-like TUI for the description of 3D form. The TUI consists of a set of plastics cubes (all 5 cm/edge) that can be connected to one another using simple male-female connectors on each face, forming both a physical form and a network topology. Each cube and cube face has a unique ID. A host PC is connected to a special base cube and communicate with the small CPUs in each cube. Since all cubes have the same size. Some ActiveCube have environment sensors (light, detector of obstacle, etc.) which increase the possibility of interaction. For instance, to approach one hand close to a sensor of some ActiveCube decreases the lighting of the structure. The intuitive use becomes less significant, just as the cognitive gap between the perception of the artifact and the perception of the data. We think the artifact lost the concept of " intuitive interface", because action of sensor can't be think ahead with the artifact form.

2.3.3 *Other applications*

There are also applications using of the specific and different tangible artifacts which are convert by a system of camera into a digital information and an action for the numerical

[1]MERL: Mitsubishi Electric Research Laboratory

data. Thus, this 3D model allows of "data life" to the artifact. Indeed, the 3D model has the physical properties of the artifact and thus modifies the numerical data such as for example in "Luminous Room" of MIT ([22]). In this application the artifact are blocks which represent mirrors with various optical properties (prism, mirror, semi-reflective mirror, etc). Once the combination created, the computer traces, actually increased, the advance of a luminous ray according to the artifact (mirror, prism). Another application within the framework of European project BREVIE (bridging real and virtual with graspable to use interface) presented in [15], [6] and [2] based on the principle of the realization of a digital 3D model with real object. The goal of this project is to allow an automatic transition between two distinct worlds for the students: the physical pneumatic circuit and the draftsmanship (3D representation).

The two first applications make it possible to combine artifacts by connected electronic and manipulate the data in intuitive way. The combination by means of connectors does not seem to us relevant, because it induces too many restrictions. Indeed, users can assemble two artifacts only face to face. The two last are TUI with artifacts closer than real object that the artifacts of ActiveCube are. Thus, in our sense, all these TUIs are not conceived and are not directed for the combination of parts. We think there is a potential to create a new interface based on TUI if we find suitable artifact.

3. ESKUA: PROPOSAL

ESKUA (figure 3) is a TUI which increase the ease of assembling and handling a combination of parts. ESKUA means "the hand" in Euskara, the Basque Language, and is the french acronym of "Exprimentation d'un Système Kinésique Utilisable pour l'Assemblage".

Figure 3: Our idea of ESKUA.

3.1 System Description

We use the term "interacteur" to define our artifacts. We choose this term because an interacteur is an object to do interaction (inter + to act on). Afterward, to describe our artifact we use the term *interacteur*. ESKUA is composed of interacteurs, a video capture system and work area. The actions which the user carries out on interacteurs (displacement, combination and rotation) are reproduced in 3D on the display screen. The capture of the position and the orientation of the set of artifact is based on a system of video capture. Its low cost and its upgrading capabilities (a number of cameras, the liberty for the choice of interacteur forms, identification with colors) seem to us very interesting assets.

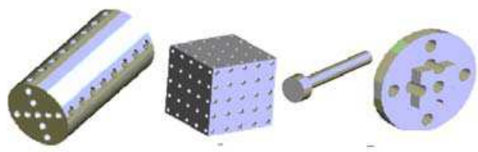

Figure 4: Samples of interacteurs : cylinder, parallelepiped, screw, graft.

3.1.1 Interacteurs

ESKUA associates each interacteur with one or a set of virtual objects. Our interacteur can be defined as "figurative", because their forms are primitive like cylinder or parallelepipeds (figure 4). They symbolize for the user a more complex virtual objects. The use of interacteur raises one question : "Why we associate an object to a concept and vice versa? ". Here, the concept is defined as [14] *"any unit of thought; a mental image formed by generalization"*. Indeed, we think that the concept makes it possible to associate a virtual object and real object. Thus the concept is the link between an interacteur and a 3D model. It seems to us [9] that during the fast identification of an interacteur we analyze the outline which is consisted of its form and its size. That's why we chose two criteria to design are interacteur : form and size.

We show in [12], that even in a complex application area (see part 3.2) two forms are rich enough for combinations as far as interacteurs of different sizes are provided. The user can add to an interacteur a surface provided with guideway or alignment, called *graft*, in order to modify the way he gathers (figure 4). The addition of graft makes it possible to limit once the number of interacteurs and secondly to offer several solutions for the assembly of parts.

A study leads us to define our interacteurs with the following characteristic. In order to be combine, there are many piercings in each interacteurs. Actually, they are proposed in three sizes : Small, Medium and Large (see table in figure 5). Our interacteurs are designed with Catia V5, CAD software from Dassault System [3]. They are machined by four axes machining centres and are made in isotropic material with a 0,65 g/cm^3 volume mass, a polyurethane resin (KUVO-15040). It's a good deal between cost and two mechanical properties important for us : small weight and wear resistant.
Here is an accurate description of our interacteurs. The size Small, Medium and Large are respectively 42, 70 et 98 millimeters in diameter for cylinders and edges of 42, 70 et 98 millimeters for the front of parallelepiped. The different depths are 14mm, 28mm, 42mm (only for the small size of parallelepiped), 56mm, 70mm (for the medium size of parallelepiped) and 98mm. The piercing is 6mm in diameter. Piercings are space out 14mm.

3.1.2 Video Capture

The user is allowed to associate any of interacteur to a virtual 3D model. Thus, all handling on interacteurs (rotation, translation) is reproduced on the 3D models. For motion capture, we intend to use model-based systems. In [5], the authors use a hand model in order to capture the hand

Size	Depth	Cylinder	Parallelepiped
		Name	Name
Small (42mm)	14mm	$C_{s,1}$	$P_{s,1}$
	28mm	$C_{s,2}$	$P_{s,2}$
	42mm		$P_{s,3}$
	56mm	$C_{s,4}$	$P_{s,4}$
	98mm	$C_{s,7}$	$P_{s,7}$
Medium (70mm)	14mm	$C_{m,1}$	$P_{m,1}$
	28mm	$C_{m,2}$	$P_{m,2}$
	56mm	$C_{m,4}$	$P_{m,4}$
	70mm		$P_{m,5}$
	98mm	$C_{m,7}$	$P_{m,7}$
Large (98mm)	14mm	$C_{l,1}$	$P_{l,1}$
	28mm	$C_{l,2}$	$P_{l,2}$
	56mm	$C_{l,4}$	$P_{l,4}$
	98mm	$C_{l,7}$	$P_{l,7}$

Figure 5: Table of interacteurs.

movements. Given a hand model in a starting pose and an input image, a model-based algorithm will make the model gradually converge to a final hand pose. We want to adapt this approach in our system. The interacteurs don't lose their forms contrary to the hand, but they are move in the space. Thus, the difference between two captured images are the translatory motion (left/right, front/back) and rotations. However, it doesn't provide enough informations to get the orientation of this interacteur. For example : a rotation of 90 degrees between two captured image is not visible. To adapt this technique for interacteurs, we will use piercing as a texture to capture more informations. Finally, we will use marks, by drawing symbols on each face, in order to recognize easily faces and their orientations.

3.1.3 Work area

We have to study and design this material part of our system. Today, we imagine it as shown figure 3.

3.2 Application area

In previous work [12], we have shown that it is interesting to tackle the general problem, to first concentrate on a particular field, in our case, mechanical design. In this specific application field we have verified that our platform concept makes it possible for a CAD designer to carry out the combination of CAD parts of a product. The proposed working environment directly confronts the designer with constraints of combination/assembly which are usually occulted by the functionalities of existing CAD software. For example, the difficulties of setting in relative position of two parts before fixing or the difficulties of insertion of a part compared to the others such as the inaccessibility or the collisions will be potentially identifiable by the designer during his handling. We think that the handling of physical objects makes it possible to bring back the combination run of the product in the real world and leads the designer to raise questions in a "natural" way by carrying out the gestures related to the assembly. To bring closer the user of ESKUA of the real activity practise by the fitter, we propose clamping system between interacteurs who are representative of the various existing technical solutions. For that, we propose (figure 4, third drawing) various sizes and types of fastenings like nut, screw, stud, spring retaining ring, etc.

The interacteurs symbolizing the parts are bored in several places (figure 4) in order to allow their combination by the preceding fastenings. With ESKUA, designer can carry out his assembly by allotting a type of interacteur to one or more parts CAD, and by handling these physical objects to carry out the assembly of the product. So the user is confronted with the real constraints of the operations of assemblies such as, for example, the difficulties of setting in relative position of the parts, maintains it in a joint way of certain elements. To simulate a such difficult task, people think ESKUA requires plenty different forms of interacteur. But, we show in [12] that two forms can be enough, parallelepiped and cylinder, for assembling. This proof is based on the analysis and description of DFA methods. In addition, certain complex parts can be represented by several interacteurs assembled between them.

4. CONCLUSION AND FUTURE WORK

In this paper, we have presenting our idea of a TUI for handling and fit together 3D models. Thus, we propose ESKUA. ESKUA means "the hand" in Euskarian, the Basque language, and is the french acronym of "Expérimentation d'un Système Kinésique Utilisable pour l'Assemblage". For now, we are working on the engineering achievements (hardware and software) of ESKUA in order to confront our ideas to the reality. We will propose a prototype version (few interacteur and a beta version software) dedicated to the CAE Domain.

5. REFERENCES

[1] D. Anderson, J. Frankel, J. Marks, A. Agarwala, P. Beardsley, J. Hodgins, D. Leigh, K. Ryall, E. Sullivan, and J. Yedida. Tangible interaction graphical interpretation: A new approach to 3d modeling. In *siggraph*, 2000.

[2] F. W. Bruns. Integrated real and virtual prototyping. *Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society (IECON 98), Aachen, Germany.*, 1998.

[3] D. S. Catia. Available on World Wild Web [may the 28th 2002]. http://www.catia.com/.

[4] A. Cho, R. Lederer, E. Sharlin, B. Watson, L. Liu, and S. Sutphen. Designing virtual worlds ? the cognitive map probe. In *Proc. 13th Western Canadian Computer Graphics Symposium (Silver Star, Canada, March)*, 2002.

[5] J.-B. de la Rivière and P. Guitton. Hand posture recognition in large display VR environments. In *Gesture Workshop*, April 2003.

[6] H. Ernst, K. Schfer, and W. Bruns. Creating virtual worlds with a graspable user interface. *Interactions in Virtual Worlds, Proceeding of the Twente Workshop on Language Technology, TWLT 15, Enscheide: Universiteit Twente, S*, pages 45–57, 1999.

[7] B. Frölich, J. Plate, J. Wind, and al. Cubic-mouse-based interactaction in virtual

environments. IEEE *Computer Graphics and Applications*, pages 12–15, juillet aout 2000.

[8] P. Fuchs, G. Moreau, and J. Papin. *Le traité de la réalité virtuelle*. Les Presse de l'École des Mines, novembre 2001.

[9] L. Garreau and N. Couture. Quel est le bon compromis entre la maquette et l'interacteur unique et symbolique ?. Note interne, LIPSI-ESTIA, juillet 2003.

[10] Y. Kitamura, Y. Itoh, and F. Kishino. Real time interaction with activecube. *CHI 2001 Extended abstracts*, 2001.

[11] K. Kiyokawa, H. Takemura, and N. Yokoya. Seamlessdesign for 3d object creation. *IEEE MultiMedia*, 7(1):22 – 33, January 2000.

[12] J. Legardeur, L. Garreau, and N. Couture. Des interacteurs pour l'assemblage mécanique en cao. *3rd International Conference: Integrated Design and Production, CPI'2003, Mekns, Maroc*, 2003.

[13] J. Pierce, R. Pausch, and B. Stearns. Voodoo dolls: Seamless interaction at multiple scales in virtual environments. In *Symposium on Interactive 3D Graphics*, 1999.

[14] O. québécois de la langue franaise. Grand dictionnaire terminologique. Available on World Wild Web [may the 16th 2002], *http://www.granddictionnaire.com/_fs_global_01.htm*.

[15] K. Schmudlach, E. Hornecker, H. Ernst, and F. Bruns. Bridging reality and virtuality in vocational training. *CHI 2000 Extended Abstracts (Interactive Poster).*, pages 137–138, 2000.

[16] E. Sharlin, Y. Itoh, B. Watson, Y. Kitamura, L. Liu, and S. Sutphen. Cognitive cubes: A tangible user interface for cognitive assessment. In *ACM CHI 2002 Conference Proceedings*, pages 347–354. ACM Press New York, NY, USA, April 20-25 2002.

[17] R. Stoakley, M. J. Conway, and R. Pausch. Virtual reality on a WIM: Interactive worlds in miniature. In *Proceedings CHI'95*, 1995.

[18] B. Ullmer and H. Ishii. The metadesk: Models and prototypse for tangibles user interfaces. In *Proceedings of UIST'97*, October 1997.

[19] B. Ullmer and H. Ishii. Emerging frameworks for tangible user interfaces. *IBM SYSTEMS JOURNAL*, 39(3& 4):915–931, 2000.

[20] B. Ullmer and H. Ishii. Emerging frameworks for tangible user interfaces. *Human-Computer Interaction in the New Millennium*, pages pp. 579–601, 2001.

[21] B. A. Ullmer. Models and mechanisms for tangible user interfaces. Master's thesis, University of Illinois, 1995.

[22] J. Underkoffler, B. Ullmer, and H. Ishii. Emancipated pixels : Real-word graphics in the luminous room. In ACM, editor, *Proceedings of SIGGRAPH'99*, August 1999.

[23] C. Ware and J. Rose. Rotating virtual objects with real handles. *ACM Transactions on CHI*, 6(2):162 – 180, 1999.