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Abstract: Many technical domains, as mechanical part assembling, or architectural design, require 3D object handling and visualization that take into account real world parameters, hidden in the numerical world. For example, while designing a mechanical part with CAD software, an engineer would like to test an assembling task so as to avoid problems as relative positioning. New devices (spatial mice, data-gloves, etc.) are too generic and don't provide the required feedback; Tangible User Interfaces (TUIs) are often based on complex techniques and require expensive and bulky hardware. Moreover, most of time they don't permit to use other objects than those initially foreseen.

In this paper, we present a TUI based platform that allows to use any everyday life real world object to handle and visualize any 3D numerical model. This platform is based on a video capture system: once a real world object, called interactor, has been acquired, it is possible to associate it with a 3D numerical model. Then, any operation (planar translation and rotation) performed with an interactor is reflected into the application. This solution is non intrusive and is based on interaction objects that are all the more in balance with the user task as they have been chosen by the application designer.

Key words: 3D Visualization, Tangible User Interface, CAD/CAM, Interaction.

1 – Introduction

Many technical domains, as mechanical part assembling, or architectural design, require 3D object handling and visualization that take into account real world parameters. For example, a common problem during the design development of a CAD part is that there is a gap between the "assembly of the part in the design department" and "the assembly of the parts in the production department". Indeed, powerful software functionalities hide real problem: relative positioning can be trivial with two mouse clicks whereas been a very reluctant task in the real world.

In other domains, taking real world parameters into account is less crucial but could enhance an application. For example, a chess player would like to keep the wooden pawn contact while playing a network game.

New devices as spatial mice or data-gloves don't suit to such applications. They allow to handle a representation of the numerical model, but don't permit to understand specific physical constraints, inherent to the represented object. For example, even if a Phantom like device is able to perform 3D object handling for six degrees of freedom, and even if it is able to provide feedback, it will never physically represent the contact between two complex mechanical parts.

Moreover, as these devices are generic, their shape, their color and even their way of interacting with a given model don't match directly with the handled object. The user has to make a mental link between the real and the numerical world.

Tangible User Interfaces (TUI) aims to solve this problem and give a physical representation of numerical data so as to handling it [1]. The tangible object represents the data (or the task to achieve) with its form, its color, its position, etc.

For this reason, we have developed a Tangible User Interface based platform. It consists of a video system that can acquire a real world object (called interactor) and associate it with a 3D numerical one. Once the association has been achieved, all the operations (translation and rotation in a plan) performed with the interactor are reflected into the application.

In this paper, we first present an overview of solutions that aim to allow 3D object handling, and we show why they are ill-adapted to the problem. Then, we describe our platform main characteristics. With this platform, the mechanical designers will associate interactors to CAD parts, and handle these physical objects to carry out the assembly of the product.

2 – Related Works

Interacting with 3D objects in 3D environments has led to develop new interaction techniques. This part deals with a generic device overview and with a TUI presentation.

2.1 – Generic Devices

A first approach consists in using generic devices, dedicated to the manipulation of all kind of 3D data. They provide a way to interact with the six degrees of freedom of an object.

As analyzed in [2], translating or rotating an object is an integral task [3]: it is not "natural" to split a move according to each axe. For this reason, in this case, interacting with the six degrees of freedom of an object with a six degrees of freedom device is more efficient [4] (Note that some 3D tasks, as object selection, are "easier" with a 2D interaction).

For example, the Roller mouse [5] and the Rockin'mouse [6] are adaptations of the common mouse. They increase the number of degrees of freedom (4 for the Rockin'mouse), and they succeed in simulating the handling of the six degrees of freedom with a context button. unfortunately, they make the user split the rotation task into several subtasks. Thus, they break down the previous principle.

As 3 degrees of freedom devices are not efficient enough to support 3D object handling, 6 degrees of freedom devices have been developed. According to [2], these 6 degrees of freedom can be handled with forces (isometric devices) or with motion and rotations (isotonic devices) they are isotonic (move in space). Zhai and Milgram [7] argue that isotonic devices are more efficient to position controls.

The Cubic Mouse [8] is an example of a 6 degrees of freedom device. It is a cube equipped with a position captor that gives information about its orientation and its motion. The mouse is crossed by three orthogonal shafts that slides throw the cube. They have been specially designed to translate cutting-out plans of a virtual scene.

The Phantom [9; 10] also owns 6 degrees of freedom, but it is a feedback device. It is handled as a pen, and is mostly used in simulation software to manipulate a tool (surgery scalpel, dentist drill, etc.). Its use has been improved with the ReachIn society disposal. In this system, the Phantom is positioned under a semi-tinged mirror, on which a stereoscopic image is projected. Thus, the handled virtual tool is visible as it was in the user hand.

The BAT system aims to localize a person in a 3D space. It is an ultrasonic location system based on the principle of position finding by measurement of distances. Bats are transmitters that emit ultrasounds. The 3D positions are computed according to times-of-flight of the pulses to known receivers. The orientation of an object can be calculated with two or more Bats attached to it.

This study first shows that the best way for controlling the position of an object is to use an isotonic device. Moreover, its number of degrees of freedom must match with the control we aim to obtain. Technically speaking, existing devices fill our requirement as they own 3 to 6 degrees of freedom. unfortunately, there is no link between the physical device and the 3D numerical object: the color, the shape and the way of handling may be totally different. This is a real problem since ReachIn society system tries to solve it with an image projection. Moreover, there may be a wide gap between the device physical characteristics and the 3D represented object: handling a spatial plastic mouse will never give any clue about the physical properties of a rough wooden piece. Finally, all the existing devices are intrusive, require a learning phase and are quite expensive.

For these reason, we propose the use of TUIs. The next subpart deals with such based systems.

2.2 – Tangible User Interfaces

As mentioned in [11], a well designed object must:

- Give clues about "how to use it";
- Own constraints that limit possible actions, so as to make main actions more efficient;
- Own a good mapping function: results of an action corresponds to the action itself;
- Display in its visible state the result of an action (feedback).

TUIs based system aim to bring these features in the interaction devices.

Since 1979 and Aish tangible interface for handling a building structure [12], many TUI based systems proposed to use real world objects as interaction devices. The term "TUI" comes from an analogy to GUI (Graphical User Interface) and has been described as a physical realization of a GUI in [1]. To refer to these objects, we use the term "Interactor". It comes from "Interaction" and "Actor" and doesn't have any relation to those described in [13; 14]. In literature TUIs are also called: *graspable user interface*, *natural user interface, tangible query interfaces*, or *artifacts, props, phycon.* Those terms are used sometimes in order to distinguish a type of TUI from another. Compartmental interfaces defined by Fuchs et al. [15] are a superset of TUIs including interfaces with active feedback, as the Phamton, and interfaces with passive feedback as TUIs.

Interactors could be divided into two categories: active and passive.

2.2.1 – Active Interactors

Active interactors are real world object equipped with electronic components, captors, wires, etc., which make it possible to get their position and orientation.

For example, ActiveCube [16; 17] is a Lego-like TUI for the description of 3D forms. It consists in a set of plastic cubes that can be connected to each others with male-female connectors. Each cube and each face owns a unique id. Thus, a set of connected cubes forms both a physical and a network topology, which can be analyzed by a host PC (connected via a special base cube).

This system allows to build as complex structures as a child would with Lego. unfortunately, this solution is not more relevant to handle a 3D object than devices of the previous section, since the cognitive gap between the object and the interactor is as wide as in a common mouse based system.

To fill this gap, an ActiveCube can be enhanced with environment sensors (light, obstacle detector, etc.) that increase its interaction potential. For example, getting the hand closer to such a cube may decrease the entire structure lighting. Unfortunately, this is not sufficient to offer the physical feedback we are looking for.

Another system [18] presents a new version of the twenty years Segal Model, which allows a user to build a virtual world from "real" walls and characters. The TUI is constituted of a table with a 24 columns and 16 rows grid. To make a wall, the user engages a sheet in the grid. To position a character, he/she puts an interactor on the table. Once all the objects have been placed, the system analyses the table configuration, thanks to electronic connections, and builds the corresponding virtual world.

In this example, there is a real matching between the interactors and the 3D model of the numerical scene. But this solution is set to a single or two types of interactors. It is not possible to use this system with new common real world objects as they have to be "pluggable".

2.2.2 – Passive Interactors

Passive interactors are real world object that don't need to be enhanced to be used in a TUI. Most of the systems based on passive interactors are video tracking based.

For example, the Luminous Room [19], a project from MIT laboratories, uses video cameras to "communicate" with the real world. In this system, wooden blocks are representing mirrors with various optical properties (prism, mirror, semi-reflective mirror, etc.). Each block is identified by a symbol and a colored dot, printed on a face. Blocks are positioned upon a table by the user(s) and spied by a camera. An application interprets the simple colored-dot-location to out-put the position, the orientation and the properties of each block. Once the capture is achieved, a luminous ray is projected on the table by the computer. The ray takes a virtual path, according to the numerical properties of the blocks, their position and their orientation.

Another approach consists in spying the motion rather than the interactors. Thus, the BREVIE project (Bridging Real and Virtual with a graspable user interface) [20; 21] aims to create digital 3D models from real objects. In this system, the user's hands are tracked thanks to datagloves, and each hand move is reflected in the virtual environment. To be usable, the system has to know the initial position of the user hands and of each interactor. Then, it is able to compute the position of the hands thanks to the datagloves, and to identify the handled interactor.

2.2.3 – Conclusion on TUIs

TUIs based on active interactors are not extensible. Each interactor has to be equipped with electronic components, and has to provide physical connectors. For this reason, such based systems can't be augmented with every day life real world objects.

Passive interactors based systems seem to be the best solution for allowing 3D object handling and visualization. Indeed, they allow to use any real world object without electronic equipment. Unfortunately, all such systems are bulky, intrusive and expensive. The Luminous Room is composed of many cameras, and transporting the entire system may require many efforts. The BREVIE solution seems not usable in a context where the user switches from a work with datagloves and a more common task (reading his mail, drinking his coffee, etc.), and where positioning the interactor in an accurate starting configuration is not easy.

For these reasons, we have designed a platform coupled to a software application that aims to solve these problems.

3 – A TUI for 3D Object Handling and Visualization

For each 3D object handling and visualization, there is a real object more appropriate than another. For example, it seems more natural to handling a 3D chess tower with a real chess tower. Moreover, assembling two mechanical parts in a CAD software will be more relevant with two real objects that owns matching surface properties. Finally, an application user will be more able to achieve a task if a "good" interactor is provided (i.e. shape, color and functions adapted to the task).

In this section, we present a platform and an application that allows to handle (planar translations and rotations) and to visualize a 3D model with any everyday life real world object. This solution is simple, transportable and cheap. Moreover user can complete his task with a system which doesn't change the working space. In our software, we need a real time video tracking. Indeed, it is still a complex problem to track on six degrees of freedom any object with one camera. We propose two video tracking algorithms in order to tackle this problem. We point out the benefits and the limits of each approach. In this context, we need a real time video tracking. Then, we focus in this part on real-time visual object tracking.

3.1 – Design Constraints

The manipulation platform has been designed according to several constraints.

We want to offer a easy and personal interactor handling environment, that can be used anywhere, from a planning department to a personal office. For this reason, it has to be integrated in a common working space composed of a desk, a computer, a phone, etc., without modifying it. Moreover, we want the system to be as accessible as possible, without hindering the user work. For example, the platform hasn't to prevent the user from performing common tasks with his/her common devices (mouse, keyboard and screen). Finally, the use of the platform has to avoid a tiring posture. To ensure this, the manipulation tray must provide a resting arm disposal.

These constraints have been detailed and formalized in collaboration with an ergonomics specialist from CRT-Innovation (ESTIA, France). The resulting recommendations have guided the design process.

Finally, we focused on the personal factor so as to propose a prototype as cheap as a PC.

3.2 – General Description

3.2.1 – Physical Components

Physically speaking, the platform consists in several components: a tray, a spot light, a webcam, a telescopic arm and a storage case (Figure 3).

The storage case contains all the other elements. It is used both to elevate the screen (the manipulation tray can be placed in front of it, without occulting the screen), and to park the platform in an optimized space.

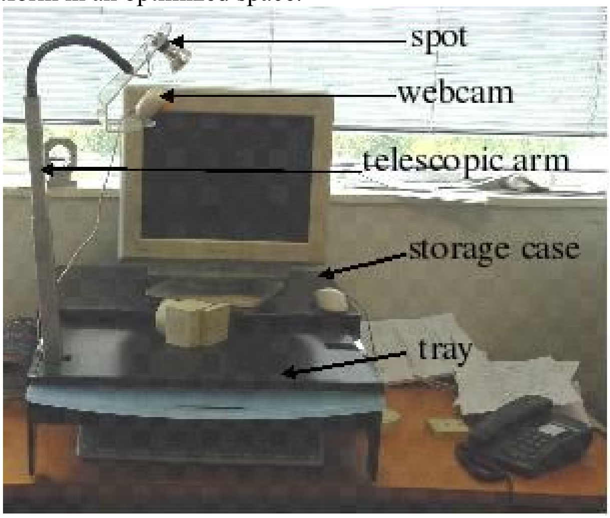

Figure 1. Platform components.

The manipulation tray is the top of a 20 cm height plastic box, which slides into the storage case as a drawer. This box is 10 cm elevated. When the tray has been getting off, the user gets access to a fully equipped telescopic arm (Figure 2) (the spot light and the webcam are set to it). This arm can be set in a vertical and adjustable position.

The spot light and the webcam are both set at the end of a telescopic arm. As the user manipulations occur on the tray, the spot light and the webcam have to be placed above it, higher enough to light and to capture the scene.

To summarize the platform installation: the storage case is placed under the screen. Then, the box is pulled off the case. The user gets the tray off and sets the arm in a vertical position. He/she closes the box with the tray, lights the spot on and begins to use the platform.

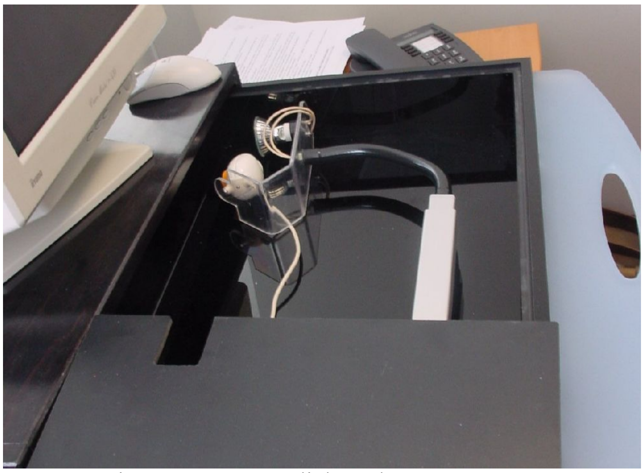

Figure 2. Arm, spot light and camera storage.

The resulting platform fills the previous requirements: its plastic structure is very light and can be moved very easily. The entire disposal can be stored under the screen. In a working position, the tray is positioned upon the keyboard and the mouse. It can be laterally translated to temporarily free the space.

3.2.2 – Software

To test our system, we have developed an application that allows to handle and to visualize 3D objects from the platform.

The application (Figure 3) consists of three frames. The frame number one (top left) lists all the 3D objects imported into the current project, and that can be associated to an interactor. Selecting an object in this list automatically displays a 3D preview in the second frame (bottom left). The object can be rotated with the mouse in a direct manipulation interaction. The third frame (right) displays all the 3D objects that have been associated to an interactor. In this scene, the objects can be moved and rotated with the set interactors.

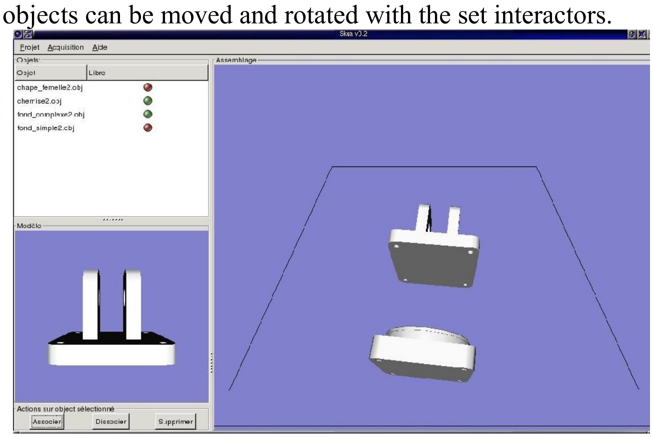

Figure 3. Main window of the test application.

To handle a given object with our platform and our application, the user has first to import the file that represents his/her object (in the current version, only OBJ files are accepted). The name of the object is then listed in the frame number one. As it has not been associated to an interactor yet, the list item contains a red light too. Then, the object has to be selected by the user: the third frame displays automatically a 3D preview of the object. Notice that this view can be rotated with the mouse: we will see later why the chosen orientation is important according to its future association with an interactor.

The user takes an interactor and puts it on the tray. He/she clicks on the “Associate” button: the 3D object is displayed in the frame, and the color of the corresponding dot in the first frame list is automatically set to green. Then, each 2D translation and rotation performed with the interactor is reflected on the object. To break an existing association, the user selects the object in the first frame list and clicks on the “Disassociate” button (the object then disappears from the scene).

The chosen orientations are very important in the association process. Indeed, the association is based on the orientation of each object (numerical and real) according to the scene. For example, let a user that makes an inversion while performing the association between a miniature car on the table, and a 3D modeled car on the screen. When he/she will move forward the car, he/she will see the matching model moving back.

3.3 – Video Tracking Solutions for any interactors

So as to capture any props (interactors) and to understand their motion, we have implemented two video recognition algorithms. That is to say, interactors are cylinders or parralelepipeds about 4 to 10 centimeters wide

The first one is a classical movement capture approach (Figure 4) that consists in identifying and tracking a single point in an image. The point is to consider a marker as a set of three points (each interactor must own three markers). This solution is time computing costless and ensures real time tracking of complex 3D objects. Unfortunately, it is not possible to get the motion of six degrees of freedom with this technique. Only three translations and one rotation in a plan can be recognized. Moreover, when two markers are getting in touch, the algorithm can’t distinguish the corresponding interactors between them (the two markers are considered as a single one). Finally, if an occlusion occurs between the camera and the three markers of an interactor, the algorithm fails to get the motion.

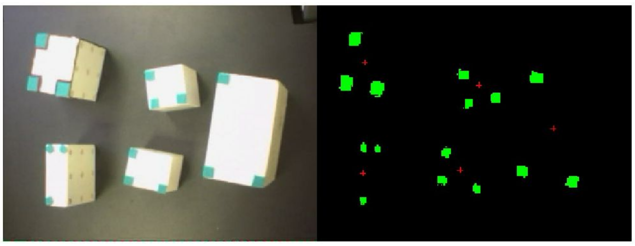

Figure 4. Image tracking based on marker approach.

So as to solve these issues, we have looked at a model based approach (Figure 5). Indeed, according to [23] that studies a hand move capture it possible to track an interactor moving in space with a single camera.

Unfortunately, our implementation of this method is far too much expensive in computing time to be applied to complex 3D model, as CAD ones are. As a result, we have obtained a ten images per second refresh rate for an object planar tracking.

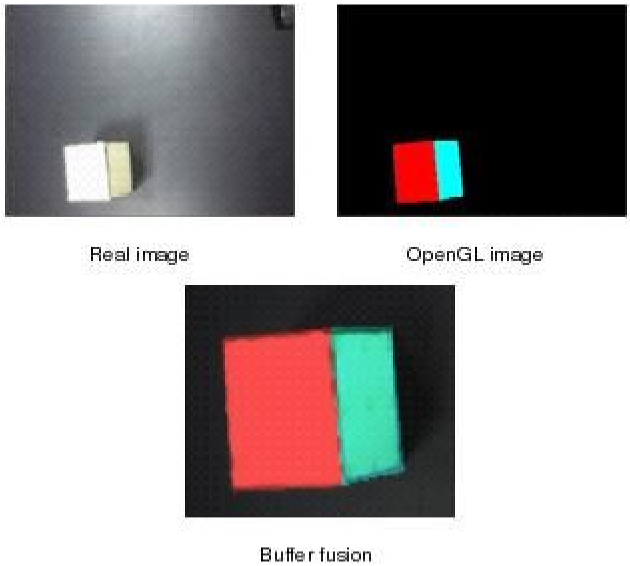

Figure 5. Model based approach: image fusion

Nevertheless, this approach seems to be a promising way. We are currently working on new heuristics, and we plan to perform new tests on an improved hardware platform. First, this includes using a software render for the creation of the 3D images that the model based approach requires. The current solution (hardware rendering) forces us to copy the 3D image from the graphical card memory to the RAM. For complexless scenes, this image transfer makes the final process heaviest than with a pure software approach.

As a conclusion, even if new hardware solutions may improve the model based approach in the future, the video tracking of interactors in a 3D scene will always cope with the occlusion problem.

4 – TUIs: a new way of interaction for CAD assembly

The mechanical parts assembly is a complex activity due to the diversity of the operations and the tacit character of mobilized knowledge. The real constraints of assembly operations (such as positioning difficulties of two parts before fixing or the insertion difficulties of one part with regard to the others related to the problems of gripping, inaccessibility of the parts, etc.) are masked by the functionalities existing in the CAD software. The use of these software based on the visualization of 3D object cannot always allow anticipation of assembly difficulties because they are “too assisted” and produce “virtual'” results. Our tangible interface seeks to make intuitive interfaces in order to couple reality and the numerical data while simplifying the interaction.

Our aim is not to replace CAD software and the associated input devices (the mouse and the keyboard) but rather to assist them for some design activities and especially during the CAD parts assembly operations. Moreover, our work not concerns the sequencing aspects of assembly but rather focus on the part grasping, handling, and insertion aspects. The goal of our work is to propose to mechanical designers a working environment based on TUI in order to enable them to be confronted with assembly constraints which are currently masked by existing CAD software functionalities.

The problem of CAD part assembly leads us to propose a new TUI dedicated to this specific application field. With real objects, handling is simple but nevertheless can lead to identification of assembly difficulties such as symmetry, occlusions, and positioning of the parts. We think that the handling of real objects makes it possible to "anticipate" some physical aspects of the product assembly phase and leads the designer to raise questions in a "natural"' way by carrying out the gestures related to the assembly.

A number of principles and technological elements are commonly used to facilitate the parts assembly process. According to the different fastening technology (welded joint, screw fastening, bolted joint, riveting, gluing, clinching etc.), we can find also removable or no removable joints in mechanical product. However, with a mechanical point of view, the parts assembly process can be described in two main steps: the first one is concerning the positioning of the respective parts; the second one is concerning the fastening of the parts between them. We can notice that the first step required to identify functional surfaces where the parts going to be joined and positioned each others. In this way, an assembly expert tends also to identify these functional surfaces in order to analyze or to optimize the assembly of the product. Therefore, we decided to develop a set of interactors (see figure 6) with specific functional surfaces commonly used in assembly process such as: chamfer on shaft and bore, fillet, flat on shaft, key and keyway, groove and groove shoulder, housing shoulder and recess, shaft shoulder, guide slot on a plane surface, internal and external spline or multiple splines, spot facing, mortice, spigot joint…

More over, "fastening interactors" is also designed to allow the use of different fastening technology such as: bolt with nut, screw, centering pin, rivet, external and internal retaining ring, pin, positioning dowel, hole-pin joint.

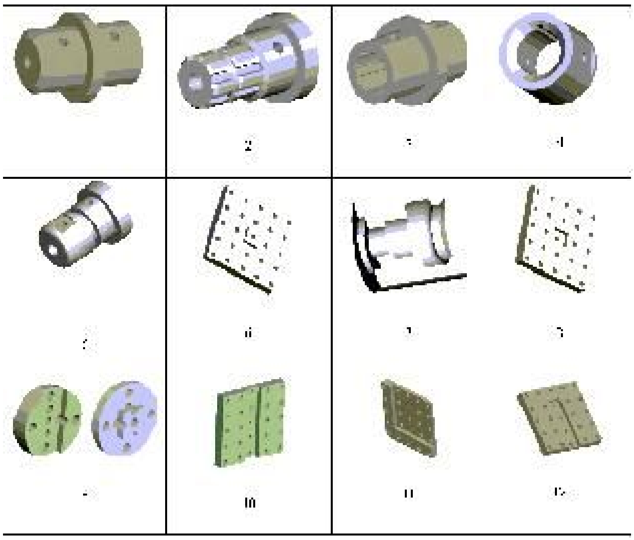

Figure 6. Model based approach: image fusion

5 – Conclusion

While more and more sophisticated devices are developed, and while techniques for using real objects as interaction tools are improved every day, neither of them allows to handle and to visualize a 3D object with any real world object. Moreover, all existing TUIs are expensive and require reluctant hardware.

In this paper, we have presented a platform and a demonstrational application that fill this gap. Thanks to a video tracking method, it is able to associate a numerical 3D model to any real world object (called interactor). Then, the motion performed with the interactor are captured and reflected it in an application that displays the 3D objects. We showed that this solution could be used in a planning department to test mechanical part assembling. Moreover, the platform relies on simple and cheap hardware, and can be integrated in any working space without hindering the user common tasks.

Nevertheless, a critical drawback still remains: even if we plan to use new heuristics, and to improve our hardware disposal, we are still not able to provide 6 degrees of freedom move to the user.

We saw that there are several methods to obtain tangible interactor's position and orientation. Video tracking solution enabled us to have a great freedom and to have a non intrusive system. But, at the moment, we track 4 dof (degree of freedom) of several interactors. It's difficult to implement an algorithm to track smalls objects with only one camera, in particular when there are occlusion of several objects movement by hand or by other object.

In 2001, at the beginning of this work, we had deliberately brush aside magnetic trackers on interactors in order to get interactor orientation and position. Indeed, these sensors are expensive - less 4 K€ - bulky – half size of an interactor - and intrusive because all provided with wire. Moreover, we should change interactors' shape to include trackers. However, we wish to preserve the video tracking solution because it's a non intrusive system and it works with several interactors' shape. In this context we will continue our researchs. We study Torré [23] work of Thalmann Team about the mixed reality in order to improve our model based approach. Changing our current camera would improve the model based approach too. A more sophisticated one (we have using a webcam) would provide clean outlines and colors. From such noiseless images, our heuristics would give better results. The next prototype of the plateform will be equipped with an analogical Sony XC-555 camera. We also look for existing solution of video tracking. ARTrack1 and ARTrack2 of Advanced Realtime Tracking GmbH are outstanding but this solution are too expensive (14000 euros and 9900 euros). At present we are testing the ARToolKit library (HITLab),of University of Washington. This library is used in mixed reality field and it permits to find the six degrees of liberty of a target. The target is a black rectangle with a white texture inside, we can see a sample in Table-Top application [24] or in application [25]. We need to test this library and certainly adapt it because the target size seems to be too large for our interactors.
To conclude, a non intrusive technic, based on one camera, of motion capture, even for
simple objects, is not still fixed. Yet, we have presented in

this paper a contribution
to solve this problem usefull in order to use TUIs in the task of CAD parts assembly.

6- References

- Article in journal :

[1] Ullmer, B., and Ishii, H. Emerging Frameworks for tangible user interfaces. Human Computer Interaction in the New Millenium, pages 579-601, 2001.

[12] Aish, R. D Input for CAD Systems. Computer Aided Design, volume 11, n°2, 1979.

[13] Myers, B. A., Giuse, D., Dannenberg, R., Vander Zanden, B., Kosbie, D., Pervin, E., Mickish, A., and Marchal, P. GARNET: Comprehensive Support for Graphical, Highly Interactive User Interfaces. IEEE Computer, vol. 23, n° 11, pages 71-85, 1990.

- PhD or books :

[2] Hachet, M. Interaction avec des environnements virtuels affichés au moyen d'interfaces de visualisation collective. PhD Thesis, Université de Bordeaux 1, 2003.

[3] Graner, W. Processing of Information and Structure. New York: John Wiley & sons, 1974.

[11] Norman, D. The Design of Everyday Things, MIT Press, 1989.

[15] Fuchs P., Moreau G., Papin J.P., Le traité de la réalité virtuelle, Les Presses de l'Ecole des Mines, 2001.

- Conferences :

[4] Jacob, R., and Sibert, L. The perceptual structure of multidimensional input device selection. In Proceedings of ACM CHI'92 Conference on Human Factors in Computer Systems, pages 211-218, 1992.

[5] Venolia, D. Facile 3D Direct Manipulation. In Proceedings of InterCHI'93, pages 31-36, 1993.

[6] Balakrishnan, R., Baudel, T., Kurtenbach, G., and Fitzmaurice, W. G. The Rockin'mouse: Integral 3D Manipulation on a Plane. In Proceedings of ACM CHI'97 Conference on Human Factors in Computing Systems, pages 311-318, 1997.

[7] Zhai, S., and Milgram, P. Human Performance Evaluation of Manipulation Schemes in Virtual Environments. In Proceedings of IEEE Virtual Reality Annual Symposium (VRAIS'93), pages 155-161, 1993.

[8] Fröhlich, B., Plate, J., Wind, J., Wesche, G., and Göbel, M. Cubic-Mouse-Based Interaction in Virtual Environments. IEEE computer graphics and applications, 2000.

[9] Chen, E. Six Degree-of-Freedom Haptic System for Desktop Virtual Prototyping Applications. In Proceedings of the First International Workshop on Virtual Reality and Prototyping, pages 97-106, 1999.

[10] Cohen, A., and Chen, E. Six Degree-of-Freedom Haptic System for Desktop Virtual Prototyping Applications. In Proceedings of the ASME Winter Annual Meeting, Dynamic System and Control, pages 401-402, 1999.

[14] Guittet, L., and Pierra, G. Conception modulaire d'une application graphique interactive de conception technique : la notion d'interacteur. Journées Francophones sur l'Ingénierie de l'Interaction Homme-Machine (IHM'93), Pub. École Centrale Lyon, Lyon, pages 151-156, 1993.

[16] Kitamura, Y., Itoh, Y. and Kishino, F. Real time interaction with active cube. CHI'01 short talks, Seattle, Washington, USA, pages 355-356, 2001.

[17] Kitamura, Y., Itoh, Y., Michihiro, K., and Kishino, F. ActiveCube: A Bi-directional Interface for Real-time Constructing and Interacting with a 3D Environment. KES 2000: Fourth International Conference on Knowledge-Based Intelligent Engineering Systems & Allied Technologies, University of Brighton, UK, pages 99-102, 2000.

[18] Schludlach, K., Hornecker, E., Ernst, H. and Bruns F. W. Bridging reality and virtuality in vocational training. In CHI'00 extended abstracts (interactive poster), pages 137-138, 2000.

[19] Underkoffler, J., Ullmer, B. and Ishii, H. Emancipated Pixels: Real-word graphics in the luminous room. In Proceedings of SIGGRAPH'99. Los Angeles, CA, USA, pages 385-392, 1999.

[20] Bruns, F. W. Integrated real and virtual prototyping. In Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society (IECON 98), Aachen, Germany, pages 2137-2142, 1998.

[21] Sutphen, S., Sharlin, E., Watson, B., and Frazer, J. Reviving a Tangible Interface Affording 3D Spatial Interaction. In Proceedings of the 11th Western Canadian Computer Graphics Symposium, pages 155-166, 2000.

[22] De la Rivière, J. B., and Guitton, P. Hand Posture Recognition in Large Display VR Environments. In Proceedings of the 5th International Gesture Workshop, Genoa, 2003.

[23] Balcisoy S, Kallmann M., Torre R., Fua P., Thalmann D., Interaction Techniques with Virtual Humans in Mixed Environments. In *International Symposium on Mixed Reality*, Tokyo, Japan, p. 81-86, 2001,

[24] Kato H., Billinghurst M., Poupyrev I., Imamoto K., and Tachibana K. Virtual Object Manipulation on a Table-Top AR Environment. In Proceedings of ISAR 2000, 2000.

[25] Billinghurst M., Kato H., and Poupyrev I. The MagicBook: Moving Seamlessly between Reality and Virtuality. In IEEE Computer Graphics and Applications. pages 2-4, 2001.