Low Cost Virtual 3D Object Visualization and Interaction

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Abstract—The importance of interaction with 3D objects has been recently reaching new higher levels with the introduction of virtual objects. The main goal is to improve the interaction with them. However, nowadays technical costs to reach such a goal are very high for most applications. This is why in the present work, a low-cost efficient and robust alternative is proposed for visualization and manipulation of 3D virtual objects.

Keywords—Hand Gestures, 3D Images Interactivity, Manipulation, Visualization.

I. INTRODUCTION

NOWADAYS, there is a developing trend toward physically interacting with objects in everyday life. The state of current technologies is allowing more flexible ways of interaction with the possibility to interact with objects without them being physically present. These virtual objects are currently at the center of several technologies, among them holography.

Holography is characterized by the presence of an object that seems to be floating in the air. Today, technologies safely allow representing holograms but the real challenge is to be able to interact with them and especially to succeed in obtaining a true tactile feedback without contact and without degrading the image itself. Obtaining a hologram can be done using lasers and mirrors. However, to get a clear and accurate picture, a complex system is needed, consisting of many lasers and mirrors of different kinds which have to be arranged in a very precise way. Such a static set comes at a significant price because of its many components. A more feasible approach is using mirrors in order to get an optical effect [1]. The Holodesk produces a floating image using a beam splitter and the user can interact with it using a Kinect [5] which is a motion detection camera developed by Microsoft. Touchable holography [7] has also been studied and achieved with the use of ultrasounds to reconstitute the tactile feeling. Mirrors and the Wiimote display have been used to represent the image and to detect the hand's position.

The goal of the present study is to create an easy-to-use and low-cost tool allowing visualization of virtual objects in 3D and their manipulation [11][15], giving the sensation to interact physically with them. The system should be a coherent and robust technology which meets the requirements of 3D representation, come at a reduced cost and be easy to handle. The necessary steps to undertake in order to achieve this project will be established first with the related constraints [2]. A detailed technical view of the proposed solution [3] will be presented after. Some applications [4] will be indicated before concluding and reflecting on the approach [5].

II. PRINCIPLE

To achieve the interaction with the object without its physical presence, there are three main steps to focus on.

A. Visual 3D Representation

The goal of the first step is to give the user an exact representation of the object in three dimensions space. It is important to have high quality otherwise the user might not feel comfortable using it, reducing in proportion the interest of the concept. Several techniques exist to achieve it depending on precision, complexity and cost.

B. Manipulation and Object Movements

The objective is to allow the user to manipulate the object. To do this, two elements are needed. First, a system to detect the user's movements, using a camera to sense the user's movements (Leap Motion, Kinect). The gesture recognition should be as efficient and as precise as possible to keep the experience entertaining. Second a program making the object move according to the captured gestures [9]. In this case, it should be responsive enough to generate smooth and fluid movements. Like the first point, different techniques exist.

C. Specific Interactions to Manipulate the Object

For the third point, the more developed the interaction features are, the more rewarding the experience will be. There are several aspects which can be added to the interaction process; for example the touch feeling [10][12] enabling the user to sense the material. So far, there are some obstacles to this because it is either too complex or too expensive. Being aware of these facts and after extended researches on the subject, a specific and new solution is developed in the following parts. With regard to time schedule and budget constraints of the academic environment where the project has been developed, only the two first points concerning visual 3D representation, manipulation and object movements are reported in the present paper.

III. PROPOSED SYSTEM

A device is proposed which allows visualization of well-defined 3D objects (such as human body parts or mechanical parts in industrial workshops), and their manipulation, giving the impression to interact physically with floating objects [13]. This device makes use of a mirror and a screen coupled with a motion-sensor to recognize movements. It will be developed as a coherent and robust technology, which meets the constraints of 3D representation at a reduced cost. A diagram of it is displayed in Figure 1.
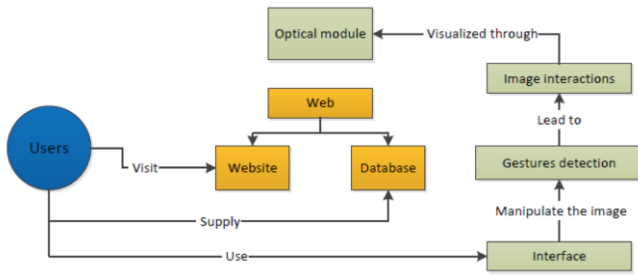
Fig. 1 Global System Display

A. Software Module

1. A hardware element: The Leap Motion controller

This device detects the user's gestures with infrared light and sends frames to the software element. It is being used within the program. Its size is 8 x 2,9 x 1,1 cm and is provided by Leap Motion. The Leap Motion has been preferred instead of the Kinect xBox360 because the Leap Motion is more precise and smaller; movements are better detected and it is cheaper.

B. 2. A software part

A program that analyzes the frames sent by the Leap Motion and that simulates some keyboard event as output if a motion control is detected. There are four motions which can be detected to animate the image:

Grab strength: The SDK (Software Development Kit) Leap Motion gives the possibility to detect the strength of a grab gesture. The Leap Motion recognizes if a hand is opened or closed thanks to the strength of the grab gesture. Only the right hand has to be detected. If the hand stays open some time, the image zooms out. If the hand stays closed for a while, the image zooms in.

A pinch with the left hand: Like the grab strength, the SDK Leap Motion can detect the strength of a pinch. This movement is used to rotate the image and only the left hand has to be detected. While a pinch is being performed, the gesture of the hand is detected and the axes of rotation follow the movements of it.

Horizontal Swipe Gesture: the SDK Leap Motion can detect the horizontal swipe gesture. When a swipe is detected with the right or left hand, we quit the 3D visualization mode.

Key Tape Gesture: simulates the click of the mouse. It is used to click on the buttons of the graphical interface and navigate through it. The user rotates his finger towards his palm and then springs back to the original position as if tapping.
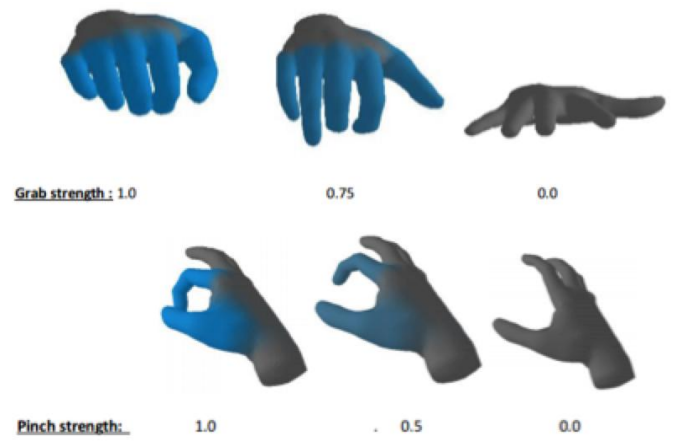

Fig. 2 Gestures Representation

This application is developed under Java with the help of an API named Java 3D. We made this choice to have a portable program so that it can run on free operating systems such as Linux, which is cheaper than Windows. Importation of the different 3D images is managed through a website developed on Wordpress. Each user can upload the image he wants to manipulate on this website. The application links with the website's database and updates the different images needed by the user.

C. Optical Module

The optical module is composed of two elements: a beam splitter and a computer screen.
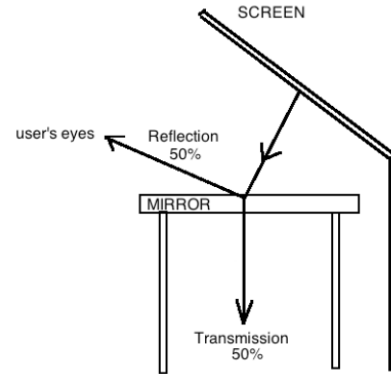

Fig. 3 Optical System

The mirror is a semi-reflecting mirror, meaning it reflects part of the light/image and lets through another. It is a 50/50 type i.e. 50% reflection and 50% transmission. The image on the screen is reflected towards the user's eyes for one part while also being transmitted through it. At the same time, the user can see his hands through the mirror. This gives the impression to be able to interact with the image. The use of a laser has been quickly dismissed at the start of the project because of expensive prices. The size of the mirror is 127 mm x 178 mm, which is practical in order to move it or to see the image.

The LCD computer screen displays the original image and the image displayed on the screen is projected onto the mirror.

IV. Results and Applications

The initial goal of developing a functional prototype has been realized at a low cost and the system is effective. The user can load and display a 3D image and handle it with good image quality. Improvements are still possible regarding ergonomics and gesture capture efficiency. Luminosity from the screen coming at the Leap Motion should be limited to improve accuracy of gesture detection.

As it stands, such a tool can be directly used in the teaching area, especially with the emergence of new methods like massive open online courses (MOOC). This method consists in further involving students in the learning process as active behavior has been recognized to ease faster and deeper memorization [2]. Providing access to new technologies such as holography based on 3D visual approach to objects allows to memorize in an even more efficient way [3][4]. Moreover, hologram interaction helps to restructure knowledge according to personal effective understanding and learning process.

More specifically, common access to this interaction modifies the teaching method in universities where students are faced with representation of complex 3D objects, such as technical and medical universities [8]. In these last ones for instance, students having difficulties with 3D representation of human anatomy [8][6] can see directly the various organs. They also get a feeling of touch on these digital resources, which provides precise anatomic details about organs or bones. More interestingly, it is expectable that students and health practitioners can get useful skills on how to diagnose some diseases involving internal organs. As the proposed system is displaying them in full 3D through a mirror, interested people can interact with them by zooming and rotating. In the same way, the proposed system is useful for manipulation, visualization and assembling of complex technical objects in specific applications with the great advantage of being able to test directly the effect of a change in material properties of interacting objects such as compliance and elasticity.

Another interesting application for its extremely large field of concerned domains consists in transforming the "floating" image into a connected object which can interact with other objects, each with its own specific characteristic parameters, which would allow testing directly interaction sensitivity with any parameter change [14].

V. Conclusion

The solution presented in the paper has three main additional values compared to other technologies which already exist in the domain of three-dimensional representation and visualization. First, the overall cost of this solution is by far cheaper than all other technologies developed in the past years, in terms of development costs as well as production costs. Second, the technology used is robust and reliable, a characteristic feature allowing the system to work in every situation without looking at surroundings and without any kind of difficulties concerning hardware installation. Finally, by its very generic approach, the proposed solution covers a large domain of applications. At the beginning the study was oriented on a more easily accessible educational objective, for which such a system represents an extremely interesting and valuable alternative. But due to its inherent robustness, applications can be extended as well to other domains of interest for the technology. For the future, the present study will be improved by allowing the feeling of textures of 3D images and the sensation of actually touching the object being displayed.

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