Learning Technical Drawing with Augmented Reality and Holograms

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Abstract: Technical drawing is very important for mechanical engineers. The ability to understand and work with technical drawings is a necessary skill for most of them. In general, first year students of mechanical engineering have difficulties in drawing orthographic views and perspectives, since they find it difficult to understand 3D shapes from 2D views. In this paper, we present several tools that we explored to help students visualize 3D models. We studied the most popular AR systems and show examples of using an AR system for the visualization of 3D models. We also present the creation of a low cost prototype, the EducHolo, that enables the visualization and interaction with holograms. With this prototype students can visualize and interact with the hologram of mechanical parts. Using augmented reality and interactive holograms we aim at providing a better perception of the model 3D shape and improving the ability of making the 2D orthographic views and perspectives that they study in the first year of mechanical engineer.

Key–Words: Visualization; Augmented Reality; Holograms; 3D models; e-learning.

1 Introduction

When students start learning technical drawing, in the first year of their mechanical engineering degree, they commonly have many difficulties in understanding and drawing the shape of three-dimensional (3D) objects from two-dimensional (2D) representations. The same is also true when they have a 3D model perspective representation of a mechanical part and they need to draw the two-dimensional front, side and top views. However, most mechanical engineers need to make and understand technical drawings, which is a fundamental tool that allows them to create designs and work with manufacturers.

In this paper, we present several examples using augmented reality and interactive holograms, that help students in the drawing of orthographic views and perspectives of technical drawings.

There are many augmented reality applications that can be used in a mobile device [1]. Similarly, there are many ways to produce an hologram [2].

Our first goal is to let students bring their own mobile devices and let them explore the 3D models using augmented reality. Tablets and smartphones are becoming less expensive and many students already bring them to classes. In this way, this paper presents an augmented reality application that enables the teacher to prepare 3D models that can be show on top of a 2D drawing in an efficient way and that do not require programming knowledge. Furthermore, the augmented reality application that we selected for this educational project is free, without any type of water marks.

Holograms are widely used in the amusement area (e.g., theaters, magic illusion, thematic parks). In this paper, we also present an interactive hologram prototype system that delivers an excellent education tool for learning technical drawing. It provides a depth impression of the analyzed three-dimensional objects which is further useful by enabling the user interaction.

The paper is organized as follows. Section 2 surveys the most common augmented reality eco-systems, the different holograms systems and the explored user interaction aspects. It is presented in Section 3 a marker based example for improving the learning of orthographic views by showing the 3D model in an augmented reality application. Section 4 presents the *EducHolo* prototype that enables students to visualize holograms with any monitor from a standard personal computer or laptop. Finally, conclusions are presented in Section 5.

2 State of the Art

2.1 Augmented Reality

Augmented reality applications combine 3-D virtual objects with a 3-D real environment in real time. Virtual and real objects appear together in a real time system in a way that the user sees the real world and the virtual objects superimposed with the real objects. The user's perception of the real world is enhanced and the user interacts in a more natural way. Virtual objects can be used to display additional information about the real world that are not directly perceived.

Paul Milgram and Fumio Kishino [3] introduced the concept of a *Virtuality Continuum* classifying the different ways that virtual and real objects can be realized. In this taxonomy scheme augmented reality is closer to the real world.

Ronald Azuma [1] defines augmented reality systems as those that have three characteristics: 1) combines real and virtual; 2) are interactive in real time; and 3) are registered in 3-D.

In general, augmented reality applications fall in two categories: *geo*-base and *computer vision* based.

Geo-based applications use the mobile's GPS, accelerometer, gyroscope, and other technology to determine the location, heading, and direction of the mobile device. The user can see 3D objects that are superimposed to the world in the direction he is looking at. However, this technology has some problems. The major problem is imprecise location which makes difficult for example the creation of photo overlays.

Computer vision based applications use image recognition capabilities to recognize images and overlay information on top of this image. These can be based on *markers*, such as QR (Quick Response), Microsoft tags or LLA (latitude/longitude/altitude), or *marker less* that recognize an image that triggers the overlay data.

There are currently many augmented reality applications and development systems for Android and iOS (iPhone Operating System) smartphones and tablets. The most popular ones are: Wikitude [4], Layar [5], Metaio [6], Aurasma [7], and Augment [8].

Wikitude delivers the Wikitude World Browser for free, which is an augmented reality web browser application, and the Wikitude SDK (software development kit) for developers which is free for educational projects. However, the educational version of the Wikitude SDK always displays a splash screen and the Wikitude logo.

The Wikitude browser presents users with data about their points of interest, which can be the surroundings, nearby landmarks or target images, and overlays information on the real-time camera view of a mobile device.

Augmented reality learning activities can be realized with the Wikitude SDK. The Wikitude SDK can be used to display a simple radar that shows radar-points related to the location based objects. It is also possible to recognize target images and superimpose 2D or 3D information on top of them. The developer can also combines image recognition and geo-base augmented reality. However, the building of these capabilities using the Wikitude SDK requires programming knowledge.

Layar has the Layar App, an augmented reality web browser, and the Layar Creator, which is a tool for creating interactive printing documents. With the Layar Creator it is very easy to make an interactive document for a teaching activity. There is no need to do any programming and, in this way, it does not require any developers with programming skills. The teacher can easily upload the trigger page to which he wants to associate augmented information. Marker less image recognition techniques are used and with the Layar Creator interface the teacher can easily associate a video, for example. Later, with the Layar App, the student can view, on the camera of his mobile device, the overlaid information associated to the page. These applications are both free. However, every trigger image published within the Layar's publishing environment is paid. For this reason, it is not affordable for developing interactive printing documents for teaching. Geo-location based augmented reality information is free of charge.

Metaio delivers the junaio, the metaio Creator and a development SDK. Junaio is the metaio's free augmented reality browser and is free. The metaio Creator is an augmented reality tool to create and publish augmented reality scenarios and experiences within minutes. With the metaio Creator the teacher can connect 3-D content, videos, audio, and web pages to any form of printed medium or 3D map (object-based or environment-based). However this tool is paid. If a user wants to develop augmented reality applications for iOS or Android, the developer can use the metaio SDK. However, this development SDK is also paid.

Aurasma delivers the Aurasma App and the Aurasma Studio. The Aurasma App is available for Android and iOS and uses advanced image recognition techniques to augment the real-world with interactive content such as videos, 3D objects or animations associated to trigger images or geo-based information. The Aurasma Studio is an online platform that lets the teacher create and publish their own augmented reality information in an intuitive and user friendly environment. It is not required any programming knowledge and every teacher can easily upload trigger images that can be associated to videos, images, 3D objects or other information. The Aurasma eco-system delivers these application for free.

Augment is a free application for Android and iOS that uses augmented reality to visualize 3D models triggered by QR codes and recently it also enables the use of a trigger image. After registering at the augment website, the teacher can easily upload a 3D model that is triggered by a QR code or an image.

Our concern is to find augmented reality ecosystems that do not require programming, that are free and easy to use for learning activities. For this reason, we chose the *Augment* systems which is free, do not require programming and teachers can prepare required learning activities in an easy way.

2.2 Holograms

In Time Machine movie (2002), directed by Simon Wells, the library scene features a hologram that hosts, communicates and interacts naturally with a time traveler. Amazingly a product of this kind to operate in its fullness does not yet exist, although there is the technology needed to develop it. On the other hand, the global communication market is increasingly demanding. Alone the existing creativity in education, media, design, advertising and marketing companies is no longer enough, especially for those companies that focus on the global market. A solution might be the use of holography to draw the attention of more users.

Holography is a technique for recording interference patterns of light which can generate or display images in three dimensions [9, 2]. Unlike photography, which only allows the record of the different intensities of light from the scene being photographed, holograms also record the phase of the light radiation from the object. The phase contains information on the relative position of each point of the illuminated object, enabling to reconstruct a three-dimensional image from that information.

Some times, an hologram is also defined as a photographic image that is 3D and appears to have depth. In this case, holograms work by creating an image composed of two superimposed 2D pictures of the same object seen by different reference points. The use of slightly offset reference points is designed to mimic the image interpreted by the human brain, which likewise receives a distinct, slightly offset image from each eye that the brain combines into a 3D image [10].

One of the most common technique to generate so called "holograms" is the Pepper's Ghost [11], due to John Henry Pepper that popularized the effect. The Pepper's Ghost is an illusion technique used in theater and in some magic tricks. In its basics, a large piece of glass at a 45 degrees angle to the audience and special lighting techniques are used, showing the audience a combination o light passing through from behind the glass and light reflecting off the glass at a 90 degree angle from the line of sight. The so called "hologram" actually is an object or image hidden from the audience and reflected off of the screen. A better effect is achieved by using dark backgrounds. An example applied to the theater and holography illustrating the entire length technique can be found in [12]. Another example is the D'Strict 3D Sensing Hologram Installation [13] product which incorporates a hologram and a monitor in a small box, that you can interact with through gestures.

2.3 User Interaction

The interaction between humans and machines can be made in many different ways, being crucial to obtain the expected level of control. Desktop or mobile applications and Internet browsing make use of Graphical User Interfaces (GUI), being currently prevalent among the available solutions. Other solutions like Voice User Interfaces (VUI) use speech recognition to control devices. More recently, multimodal interfaces [14] allow humans to interact with machines in a way that cannot be achieved with other interface paradigms.

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One of the new paradigms for human computer interaction (HCI), are the three-dimensional (3D) sensors, such as Kinect [15], Leap Motion [16], Struture Sensor [17], Asus Xtion [18]. Those can be used to interpret specific human gestures, enabling a completely hands-free control of electronic devices, the manipulation of objects in a virtual world or the interaction with augmented reality applications. These tracking and gesture recognition sensors have a huge importance mainly in the videogames industries, but these sensors, with appropriate software, have the capability of detecting the user skeleton and/or the user hand, while replicating with accuracy the user movements in a 3D mesh.

There is in the literature an enormous amount of applications, where gesture recognition and tracking is referenced, e.g., interactive art installations [19], applications to help disable or old people [20], air painting application [21], robotic arm manipulation [22] or applications in sign language [23].

We chose the Leap Motion sensor [16, 21, 22, 23] for the prototype presented in this paper due to its size, price and specific range of applications. It is a recent, but widely known sensor for hand, fingers and gesture recognition, with a very high accuracy and speed, which uses two monochromatic IR cameras and three infrared LEDs, for more details see [24]. A smaller observation area and a higher resolution differentiate it from the Kinect and Asus Xtion sensors, which are more suitable for body tracking.

3 The use of Augmented Reality in drawing orthographic views

First year students of Mechanical Engineering learn the basic concepts and techniques of technical drawing as a language definition and transmission characteristics of systems and industrial products, with gradual introduction of the use of computer aided design (CAD) systems. However, when students start learning technical drawing, in the first year of their studies, they commonly have many difficulties in understanding and drawing the shape of objects from two-dimensional representations. The same is also true when they have a representation of the 3D model of a mechanical part and they need to draw the front, left and top views.

Wu and Chiang [25] show that applying animations provided more enthusiasm for the learning activity, better performance in understanding the appearances and features of objects and improve the spatial visualization capabilities.

This section presents examples of using interactive augmented reality tools to show 3D models that are used to help students improve learning of orthographic views.

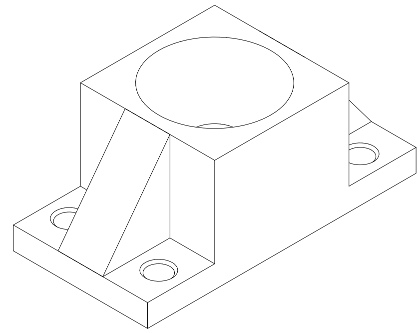

Figure 1: The isometric drawing of model 1.

Our first approach is to let students use their tablets or smartphones to visualize 3D models using augmented reality. Students use an iOS or Android augmented reality free app to show 3D models that are used to help them improve their understanding of the shape of the 3D model enabling them to draw the orthographic views.

For this purpose, the first thing the teacher needs is a 3D modeling tool. At our faculty, most teachers use AutoCAD which is free for education. With AutoCAD, teachers can create 3D models that are stored as *dwg* files. If the teacher wants, it is also possible to add textures to the model and make it look like a real object, made of wood for example.

In this way, it was easy to create the 3D model that is represented in an isometric view (see Figures 1 and 2).

To help students visualize and understand this 3D model, we used augment reality to render the 3D model in a mobile device triggered by a QR code, an image trigger or a *url* link. Figures 3 and 4 presents the visualization of the augmented 3D models corresponding to the previous representations of the 3D models that the student can use to draw the orthographic views.

Students with the help of the 3D augmented models draw the corresponding front, left and top orthographic views (Figures 5 and 6, respectively).

In present time, with the Augment application, we are replacing educational materials with virtual ones. Students can feel as if they have the actual material by watching the 3D virtual object from various orientations with a tablet or a smartphone. In this way, we provide various educational materials for each student rapidly, easily and with no extra cost.

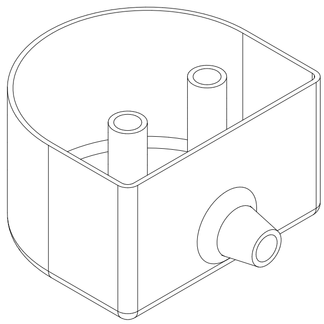

Figure 2: The isometric drawing of model 2.

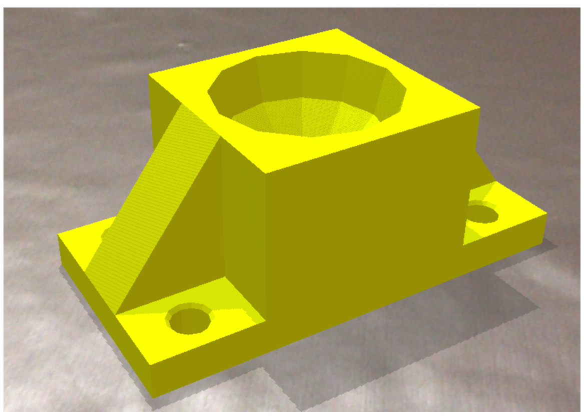

Figure 3: Visualization of the 3D model 1 with the Augment application.

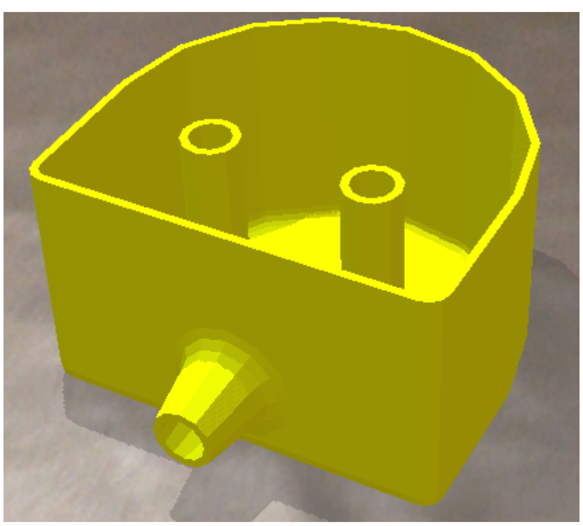

Figure 4: Visualization of the 3D model 2 with the Augment application.

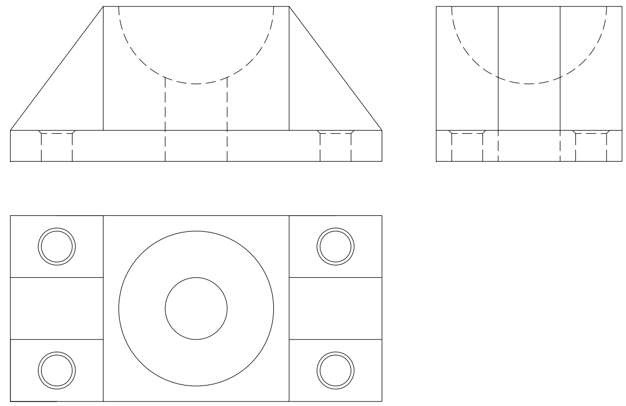

Figure 5: The front, left and top views of the 3D model 1.

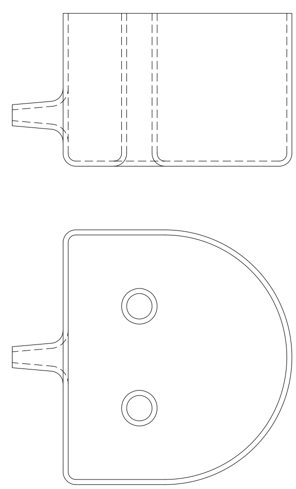

Figure 6: The front and top views of the 3D model 2.

4 Interacting with Mechanical Holograms

A different, but complementary tool to help students visualize the 3D models for better understanding of their shapes, is the use of interactive holograms. This section starts by presenting the implementation of the interactive component that allows the interaction with the holograms. Then, we present the example of using interactive holograms to help students draw the orthographic views.

4.1 3D Gesture Recognition with Leap Motion

Leap Motion [16] has an application Programming Interface (PI) capable of detecting multiple hand gestures, such as straight line movement by hand with fingers extended, a circle movement by a finger, a forward tapping movement by a finger or a downward tapping movement by a finger. These gestures (swipe gesture, circle gesture, screen tap gesture and key tap gesture) can be seen in [16] or in [26].

For each of the gestures there are a few optional configurations properties, to improve gesture detection. For example in a circle gesture, where the user can do a circle with a finger, there are two properties selectable: minimum radius and minimum arc (by default, minimum radius is set to 5*mm* and minimum arc set to 1.5π radians). For a swipe gesture, there are also two properties selectable, minimum length set by default to 150*mm* and minimum velocity set to 1000*mm/s*. These are examples of the "out of the box" gestures, possible to retrieve with Leap Motion PI.

It is also possible to join some of these gestures with the positions and rotation of each finger and both hands at the same time to recognize other gestures, such as, open or close hand, zoom in or out, done with one or both hands. For the development of the interface it was pretended the minimum of movements and the most intuitive ones - the swipe, was considered the best approach. Thus, swipe gesture was the gesture mainly used in the interface developed in this paper, e.g., for the interaction with the 3D holograms of the mechanical parts.

After regulating the minimum length swipe and velocity to the default values, it is possible to detect swipe gestures at any direction. Leap Motion PI has a direction vector for the swipe gesture, after a gesture is completely recognized, it is associate with a 3D direction vector. This vector have values ranging from negative 1.0 to positive 1.0.

As shown on Fig. 7, the Leap Motion "sees" the 3D space with standard Cartesian coordinate system,

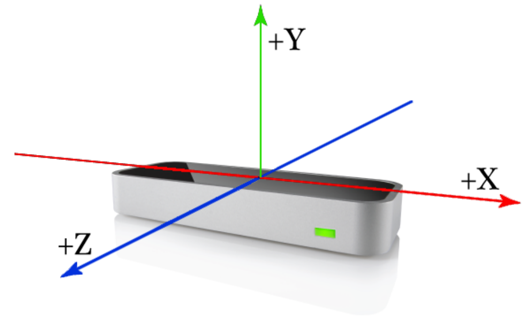

Figure 7: Leap Motion coordinate system [26].

also known as right-handed orientation. The origin of the coordinate system is centered at the top of the device, being the front of the device, the side with the green light (see Fig. 7). The x-axis is placed horizontally along the device, with positive values increasing from left to right. The z-axis is placed also on horizontal plane, perpendicular with x-axis with values increasing towards the user (the front side of the device). The y-axis are placed is the vertical, with positive values increasing upwards (see Fig. 7).

As a swipe gesture can be any swipe that meets the minimum length and velocity configurations properties, and they can obviously have any direction. As this gesture is the only used, it is needed to detect various types of swipe. The interface was designed to react to two of the six different independent types of swipe gestures as shown by Fig. 8, three of each swipes are the opposite of the other three:

(i) Up and Down: is realized by a top to bottom swipe or a bottom to top swipe respectively (y-axis).

(ii) Front and Back: is realized by a front to back and back to front swipes (z-axis).

(iii) Left and Right: is done by a left to right and right to left swipe respectively (x-axis).

In the first case, (i), of a top to bottom or bottom to top swipe, the movement depends mainly on the y-axis. If the direction vector has an upward direction ($y \approx +1$) then "deselect" action has occurred, otherwise, a vector with a downward direction ($y \approx -1$), it is considered "select" action. Since it is almost impossible to do a swipe gesture with a vector direction component of exactly

$$x = 0 \wedge y = \pm 1 \wedge z = 0, \quad (1)$$

it is needed to select a range of values to detect and differentiate between swipes types. Any swipe direction that agrees with the condition

$$y \leq -0.5 \wedge |x| \leq 0.5 \wedge |z| \leq 0.5, \qquad (2)$$

is considered as a downward swipe. Contrariwise, if a swipe direction agrees with the condition

$$y \geq -0.5 \wedge |x| \leq 0.5 \wedge |z| \leq 0.5, \qquad (3)$$

then it is considered an upward swipe.

In the second case, (ii), we need to analyze mainly the z-axis. As shown on Fig. 7, a vector with z-direction value approximately equal to 1, is considered to be a back to front swipe, otherwise, a front to back swipe. Similar to (i), any swipe direction that agrees with the condition

$$z \leq -0.5 \wedge |x| \leq 0.5 \wedge |y| \leq 0.5, \qquad (4)$$

is considered a front to back swipe. Contrariwise, if a swipe direction agrees with the condition

$$z \geq -0.5 \wedge |x| \leq 0.5 \wedge |y| \leq 0.5, \qquad (5)$$

then it is considered a back to front swipe.

In the last case, (iii), similar to (i) and (ii), x-axis is the principal axis. Any swipe direction that agrees with the condition

$$x \leq -0.5 \wedge |y| \leq 0.5 \wedge |z| \leq 0.5, \qquad (6)$$

is considered a right to left swipe. Contrariwise, if a swipe direction agrees with the condition

$$x \geq -0.5 \wedge |y| \leq 0.5 \wedge |z| \leq 0.5, \qquad (7)$$

then it is considered a right to left swipe.

These swipes are mutually independent. For every type of swipes there are only one possible choice, see Fig. 8.

4.2 Interactive Holograms to Help Students Learning Technical Drawing

This section describes the use of interactive holograms for the visualization of 3D models to help students make and understand technical drawings. In this case, we use a computer display or a projector can also be used for the visualization of the hologram using Pepper's Ghost technique. For that, the only material needed is a transparent polyester film, for a cheap and easy implementation solution, or a sheet of glass. Fig. 9 shows a diagram of the structure where the film/glass is placed at at roughly 45 degree angle relative to the computer monitor, which is placed horizontally at the top of a table. The monitor presents the models (preferably over a dark background for

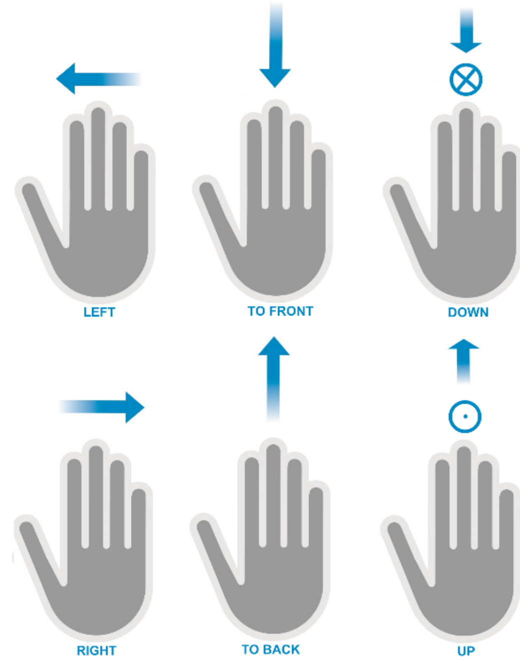

Figure 8: Six types of swipes possibles with LeapMotion gesture recognition.

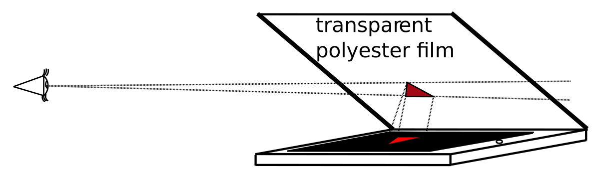

Figure 9: Diagram of the structure used to implement the holographic display.

a finest experience) and the person is placed such that he can see the reflection of the object's image on the film/glass, which gives an 3D illusion of the model. To improve the illusion, the background behind the film/glass should be a dark hall and the model displayed in the tablet animated. Another important factor to improve the illusion, common to this kind of solutions, is to keep the room in a blackish environment.

Figures 10 and 11 show two examples of holograms achieved with the describe device. In the first case the previously explored model 1 was used and, in the second case, the also already presented model 2. It is important to note at this point that the prototype presented in Figures 10 and 11 cost less than 10Euros, it is made simply of an aluminum structure with some bolts and one acetate usually used in any classroom. Better results can be achieved when using a Mylar film.

In this prototype the student can interact with the

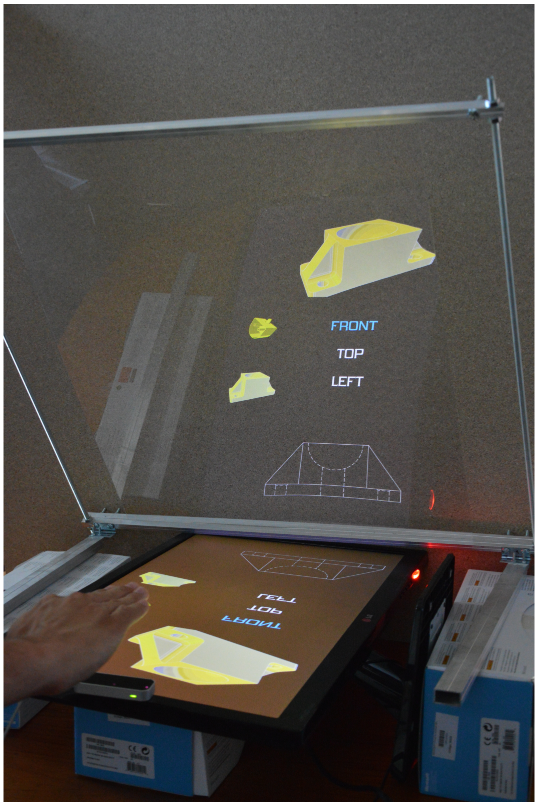

Figure 10: Interactive hologram visualization of the 3D model 1 with the EducHolo.

holograms with the integrated Leap Motion sensor. To use it, the student places its hands in front of the device, not too close, nor too far (in height and width). In this way, the student experience in enhanced. This sensor gives the student the ability to interact with the representation of the 3D models.

Currently several solutions can be used to make such 3D representation. We decided to use the Unity cross-platform game engine [27]. Unity is a game creation system developed by Unity Technologies that includes a game engine and integrated development environment (IDE). It is currently used to develop video games for web sites, desktop platforms, consoles, and mobile devices. It is now the default software development kit (SDK) for the Nintendo Wii and has been extended to target more than fifteen platforms [27]. This platform is also the ideal one to create the graphics interfaces for our application.

In this way, we developed the hologram application interface in Unity 3D [27], with three different zones: the video, the menu and the views. Figures 10 and 11 show the interface in operation. In the top, the system shows the 3D model perspective that is rotated and the student understands, in this way, its shape. As explained previously, there are six different swipes the user can do to navigate in the interface with Leap Motion. Only two were used, the (i) to select the front, top or left views and (iii) to select the 3D model and, where the respective perspective is played.

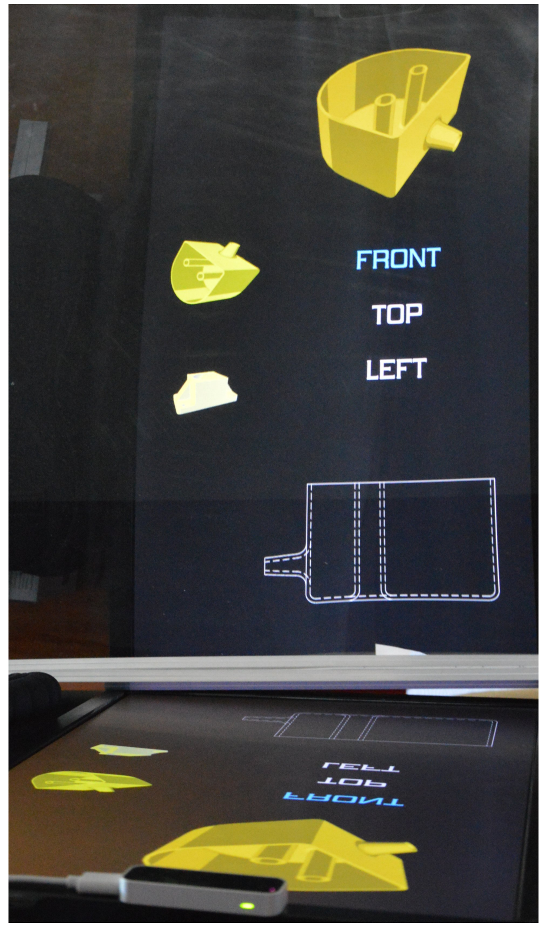

Figure 11: Hologram visualization of the 3D model 2.

5 Conclusions

We explored the most popular augmented reality applications available for tablet devices. In this paper, we looked augmented reality applications that could be used for teaching technical drawing in the first year of mechanical engineering. Such application should be user friendly, free and do not require programming knowledge, such that, every teacher can use them in everyday learning activities.

We chose the Augment application to show 3D models on top of trigger image or a QR code. In this way, students explore the visualization of the 3D models with a mobile device and they better understand the model shape to draw the orthographic or the isometric views.

In this paper, we also show that with a low cost installation it is also possible the holographic visualization and interaction with the 3D models. This will

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improve the comprehension of the model before and during the process of learning how to draw it. It is also shown the use of a Leap Motion sensor in this prototype for the interaction with the hologram. The prototype makes use of easy achievable materials (polyester films or glass) that in conjunction with monitor capacity to display good quality images and videos produce an helpful device to help the students in the visualization of the studied models.

In the future we pretend to test these two technologies in a full classroom context, creating two groups: one of control, and the other where these technologies are going the be applied during a semester. At the beginning and at the end of the semester inquiries are going to be applied to the two groups and final conclusion will be taken for a final validation of this "prove of concept".

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