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Procedia - Social and Behavioral Sciences 103 (2013) 174 – 180

Procedia
Social and Behavioral Sciences13th International Educational Technology Conference

Augmented Reality-based Support System for Teaching Hand-drawn Mechanical Drawing

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Abstract

This research aims to reduce the time, effort and monetary cost needed for developing various educational materials for teaching hand-drawn mechanical drawing by replacing actual educational materials with virtual ones on an augmented reality (AR) -based support system. This system is used for training of sketching and orthographic projection drawing, and has following features. 1) The virtual educational materials constructed by using 3D-CAD are superimposed to a real-time camera image as AR objects. 2) Students can watch the objects from various directions by using a cubic-marker intuitively. 3) The objects are applied realistic textures similar to the actual materials.

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Selection and peer-review under responsibility of The Association of Science, Education and Technology-TASET, Sakarya Universitesi, Turkey.

Keywords: Augmented Reality, Education in Engineering, Education Support System, Educational Application

1. INTRODUCTION

In this research, we developed an augmented reality-based support system for teaching hand-drawn mechanical drawing at a faculty of mechanical engineering of a university. Recent industrial products are mainly designed by using computer aided design system called, CAD. Therefore most of the faculties of mechanical engineering teach the mechanical drawing by using CAD. Though the above situation, our faculty thinks that it is necessary and important for the students to learn the hand-drawn mechanical drawing. So firstly we teach hand-drawn mechanical drawing, and after that we teach by using CAD. We think that learning the hand-drawn mechanical drawing is not only to learn the drawing skills, but also it is able to learn the stereognostic sense

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effectively. Here, we define the stereognostic sense as an ability of understanding a shape of three-dimensional object and then drawing it onto a two-dimensional drawing.

We are using mechanical parts such as gears, bearings as educational materials on teaching the hand-drawn mechanical drawing. Each student draws a mechanical part by using sketching or the third angle orthographic projection drawing, while he has the part in hand and watches it from various orientations. Through the above learning, he will have mastered the stereognostic sense. On the other hand, there are problems to maintain those educational materials. In order to give the materials to each student, we have to maintain various parts, but it requires the time, effort and monetary cost.

In this research we aim to reduce the above problems by replacing actual educational materials with virtual ones on an augmented reality (AR) -based support system. This developed support system overlays virtual materials on the digital camera image. Student can feel as if he had the actual material by watching the virtual object from various orientations by using the system. As the result, we can provide various educational materials for each student rapidly, easily and low cost.

This paper describes the structure of the system and then shows some demonstrations of the system.

2. DEVELOPMENT OF AR-BASED SUPPORT SYSTEM

This section describes the system configuration of the developed AR-based support system.

2.1. Overview and Structure

The developed AR-based support system recognizes a cubic AR marker from a digital camera image and overlays a virtual mechanical part made by 3D-CAD as educational material on the image.

The hardware of the system is composed of a personal computer and a digital camera. The software of the system is constructed by using some programming library, such as ARToolKit, OpenCV and OpenGL. The ARToolKit is a programming library for implementing augmented reality application. A virtual object is overlaid on an AR marker taken by the digital camera. Position and orientation of the virtual object is defined by recognizing the position and the orientation of the AR marker. Figure 1 shows the procedure of how to overlay the virtual object on AR marker by ARToolKit.

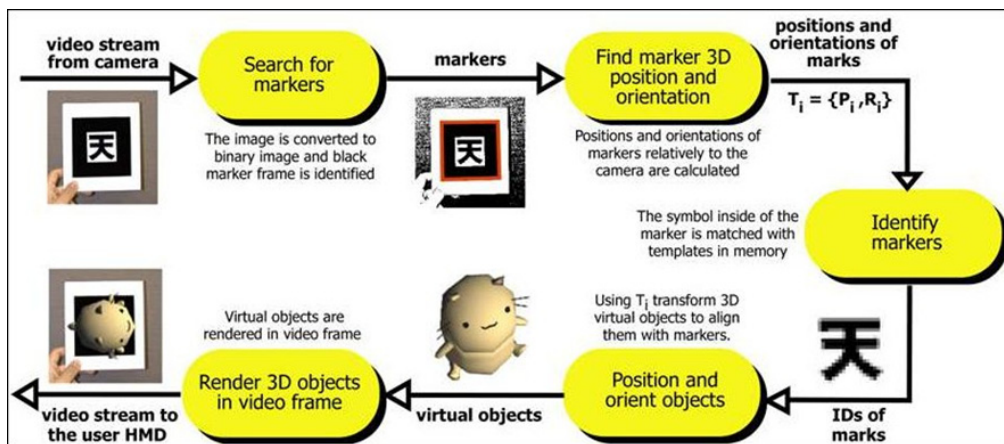


Fig. 1. How to overlay a virtual object on an AR marker by ARToolKit

(Quote from <http://www.hitl.washington.edu/artoolkit/>)

2.2. Cubic AR Marker

The AR system displays virtual objects as if they existed on real world. In order to do so, the system needs to recognize the position and the orient of the objects. It is called registration. An example of a procedure of the registration to overlaying a virtual coordinate into a real coordinate is shown in Fig. 2. At the registration, the direction and the distance of a virtual object from a camera is calculated by recognizing edges of an AR marker using a binarized camera image.

Our support system uses a cubic AR marker for the registration. The cubic AR marker provides recognition of every aspect of virtual object to the system. Each student takes the cubic AR marker in hand and watches it from various directions of front, back, top, under, left and right. It serves a user experience similar to holding an actual educational material in hand. A drawing of the cubic AR marker is shown in Fig. 3.

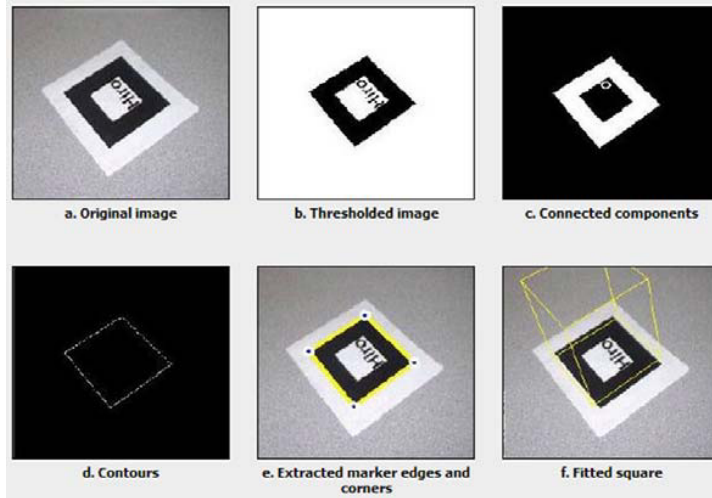


Fig. 2. How to recognize AR marker from camera image by ARToolKit
 (Quote from <http://www.hitl.washington.edu/artoolkit/>)

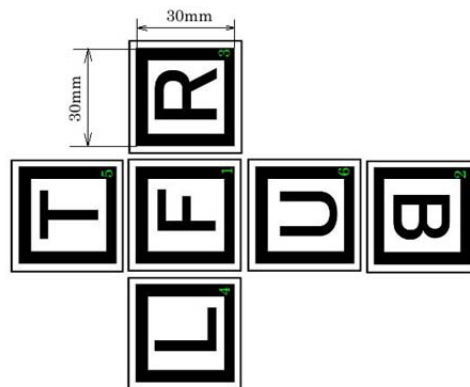


Fig. 3. Drawing of cubic AR marker.

2.3. Realistic Texture of Material

Colors of materials which are expressed by setting various color tones provide realistic textures to the educational materials. The textures are set by using `glMaterialv()` function of OpenGL library. Various textures of materials are expressed by controlling the `glMaterialv()` function parameters, Ambient Light Reflection Coefficient (`GL_AMBIENT`), Diffuse Light Reflection Coefficient (`GL_DIFFUSE`), Specular Light Reflection Coefficient (`GL_SPECULAR`) and Shininess Coefficient (`GL_SHININESS`). Some examples of these control parameters are shown in Table 1.

3. RESULTS

In this section firstly, we demonstrate some examples of the operation of the system, and then we show the effectiveness of the cubic AR marker and the expression of realistic texture.

3.1. Demonstration

The windows of the system are shown in Fig. 4. The upper is main window and it displays overlaid virtual object. The lower right window displays source image and the lower left window displays binarized image. Although the lower windows are not necessary at the actual use, we show them in order to explain our system here.

Four examples of the mechanical parts for educational materials are shown in Fig. 5. These examples of a knuckle joint, a gear, an L shaped bracket and a bearing holder were made by using CAD. The left object is the virtual mechanical part and the right one is the actual part. Each virtual object seems similar to the actual one.

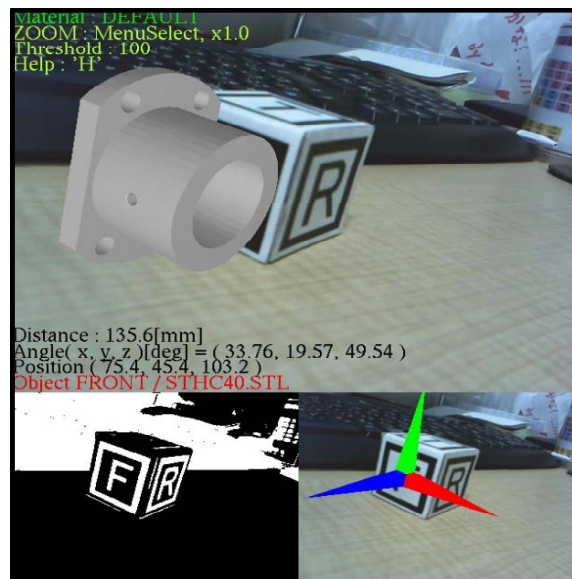


Fig. 4. Window of the AR-based support system.

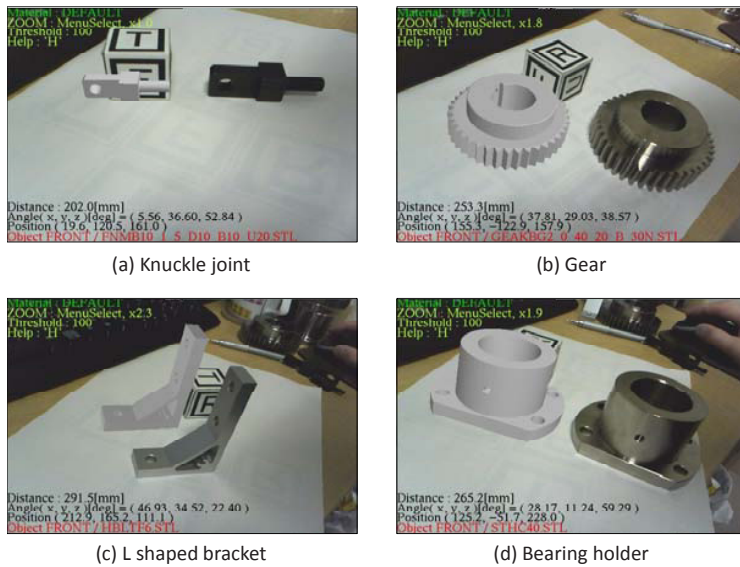


Fig. 5. Example of the mechanical parts for educational materials.

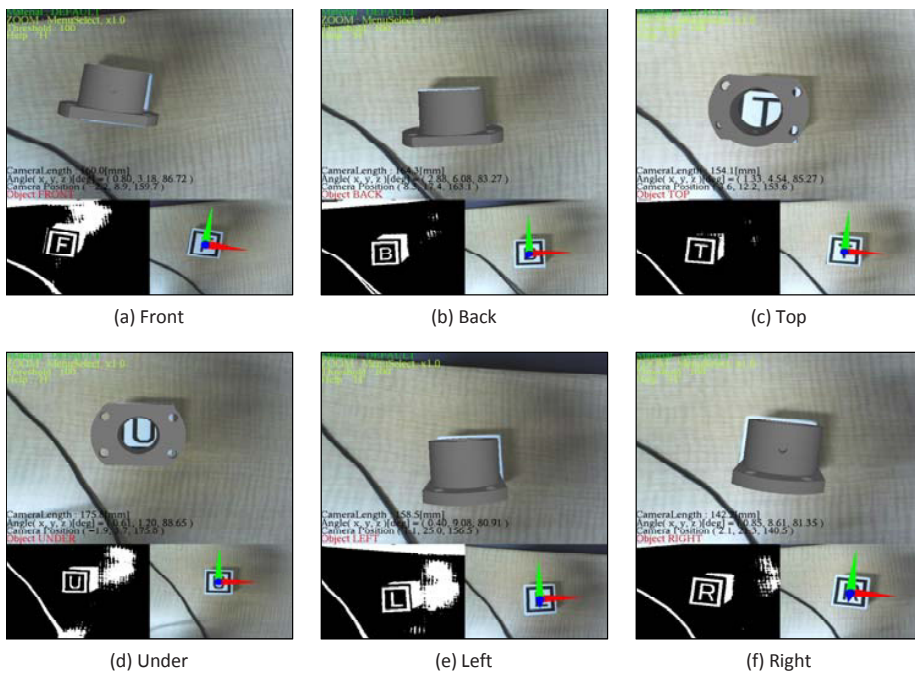


Fig. 6. Recognition of orientation by using cubic AR marker.

3.2. Cubic AR Marker

Result of the recognition of each orientation by using a cubic AR marker is shown in Fig. 6. From the Fig. 6, we can confirm that the cubic AR marker recognized exact orientation and provided various aspect of the virtual object successfully. This result shows that students can watch any aspect of virtual object intuitively.

3.3. Realistic Texture of Material

Texture of each material is set by selecting any texture from a list on window shown in Fig. 7. When user selects any texture, the control parameters shown in Table 1 are used to paint the virtual object. Presently, we prepare 25 textures. Examples of any texture painted on virtual object are shown in Fig. 8.

Table 1. Control parameters of texture of materials

Name of material	RGBA of GL_AMBIENT	RGBA of GL_DIFFUSE	RGBA of GLSPECULAR	GL_SHININESS
Default	0.45/ 0.45/ 0.45/ 1.0	0.60/ 0.60/ 0.60/ 1.0	0.04/ 0.04/ 0.04/ 1.0	0.60
Turquoise	0.10/0.19/0.17/1.0	0.40/0.74/0.69/1.0	0.30/0.31/0.31/1.0	0.10
White Plastic	0.0/0.0/0.0/1.0	0.55/0.55/0.55/1.0	0.70/0.70/0.70/1.0	0.25
Black Rubber	0.02/0.02/0.02/1.0	0.01/0.01/0.01/1.0	0.40/0.40/0.40/1.0	0.78
Brass	0.33/0.22/0.027/ 1.0	0.78/0.57/0.11/1.0	0.99/0.94/0.81/1.0	0.22
Bronze	0.21/0.13/0.054/1.0	0.71/0.43/0.18/1.0	0.39/0.27/0.171/1.0	0.20
Chrome	0.25/0.25/0.25/1.0	0.40/0.40/0.40/1.0	0.77/0.77/0.77/1.0	0.60
Copper	0.19/0.074/0.023/1.0	0.70/0.27/0.083/1.0	0.26/0.14/0.086/1.0	0.10

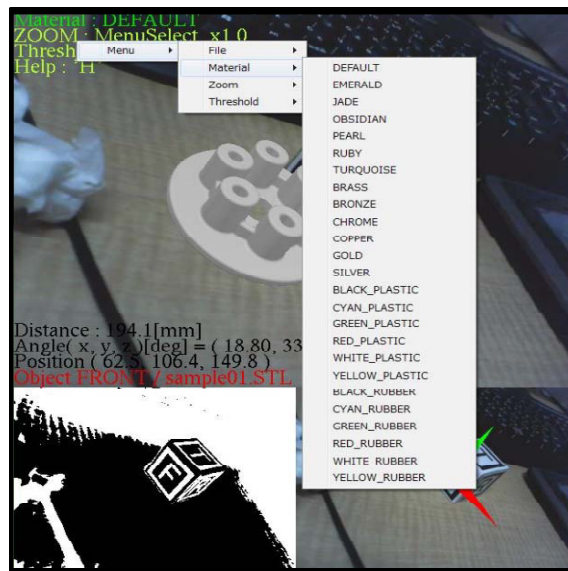


Fig. 7. Window of material list for selecting texture.

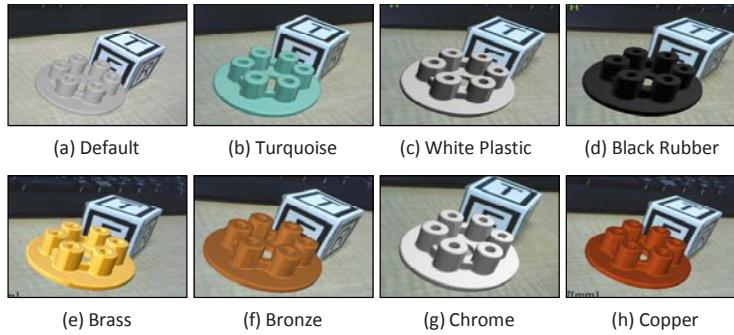


Fig. 8. Examples of texture.

4. CONCLUSION

In this paper, we showed an AR-based support system for teaching hand-drawn mechanical drawing. The virtual educational materials were made by using 3D-CAD. Easy and intuitive user experience was achieved by using cubic AR marker and realistic texture. As the result, this system achieved the reduction of time, effort and monetary cost for preparing various mechanical parts as educational materials by replacing actual materials with virtual ones.

Head-mounted display, HMD is becoming familiar in recent years. We think that implementing our system on HMD will improve usability and we aim it as our future work.

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